US009592600B2

(12) **United States Patent**
Seith et al.

(10) **Patent No.: US 9,592,600 B2**
(45) **Date of Patent: Mar. 14, 2017**

(54) **ANGLE IMPACT TOOLS**

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(73) Assignee: **Ingersoll-Rand Company**, Davidson, NC (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 323 days.

(21) Appl. No.: **14/251,552**

(22) Filed: **Apr. 11, 2014**

(65) **Prior Publication Data**

US 2014/0216775 A1 Aug. 7, 2014

Related U.S. Application Data

(63) Continuation-in-part of application No. 13/033,241, filed on Feb. 23, 2011, now Pat. No. 8,925,646.

(51) **Int. Cl.**
B25F 5/02 (2006.01)
B25B 21/02 (2006.01)

(52) **U.S. Cl.**
CPC ***B25F 5/02*** (2013.01); ***B25B 21/026*** (2013.01)

(58) **Field of Classification Search**
CPC B25F 5/001; B25B 21/00; B25B 13/467; B25B 13/481; B25B 17/00; B25B 21/002; B25B 21/02; B25B 21/026; B25B 23/1475

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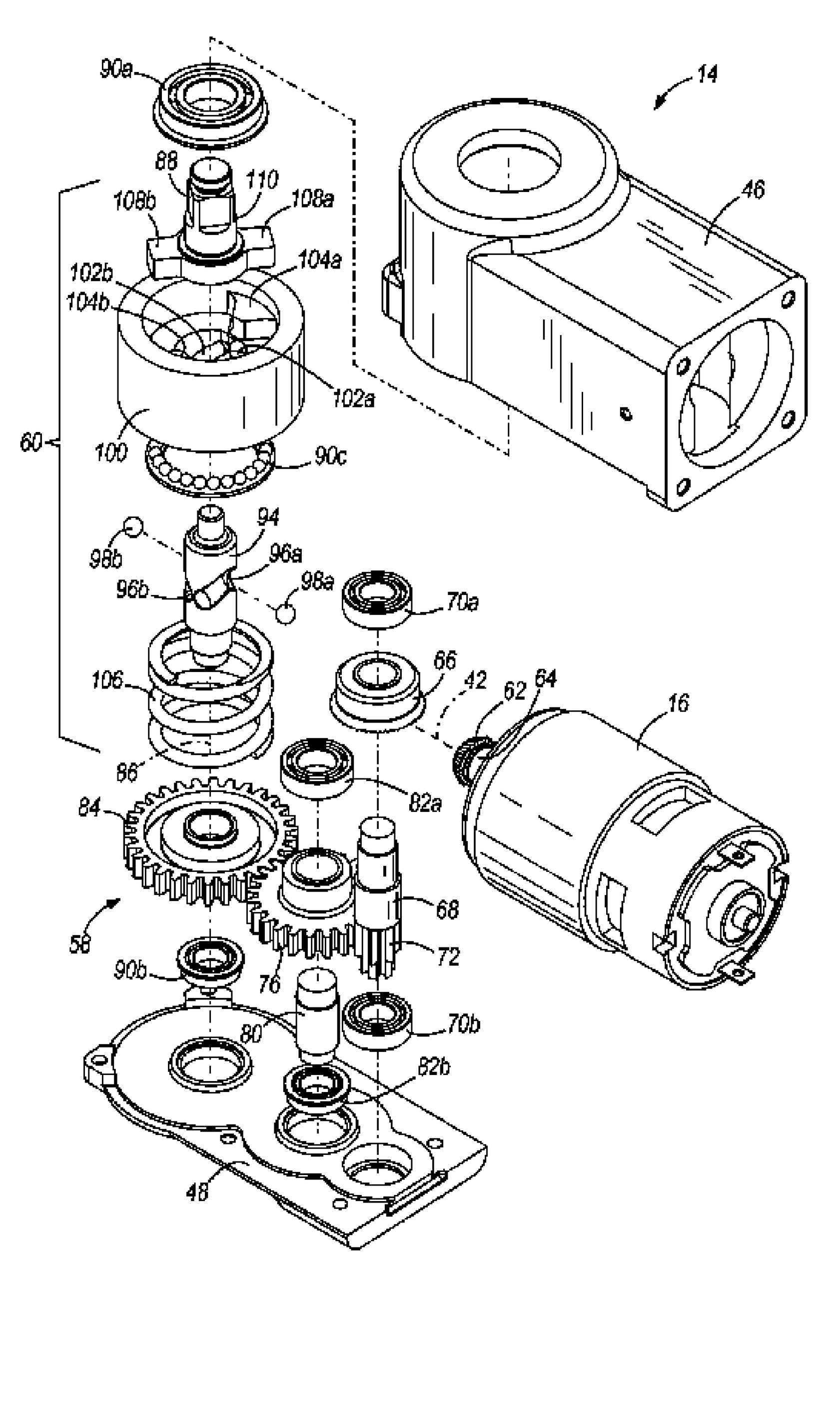
Primary Examiner — Michelle Lopez
(74) *Attorney, Agent, or Firm* — Barnes & Thornburg LLP

(57) **ABSTRACT**

In at least one illustrative embodiment, an angle impact tool may comprise a handle assembly extending along a first axis and supporting a motor, the motor including a shaft configured to rotate about the first axis, and a work attachment coupled to the handle assembly. The work attachment may comprise an impact mechanism including an anvil configured to rotate about a second axis that is non-parallel to the first axis and a hammer configured to rotate about the second axis to periodically deliver an impact load to the anvil, a gear assembly configured to transfer rotation from the shaft of the motor to the hammer of the impact mechanism, and a housing supporting the impact mechanism and the gear assembly. The housing may be partitioned along a first parting plane that is perpendicular to the second axis such that the housing includes first and second housing sections.

17 Claims, 15 Drawing Sheets



(58) **Field of Classification Search**
USPC 173/109, 217, 216
See application file for complete search history.

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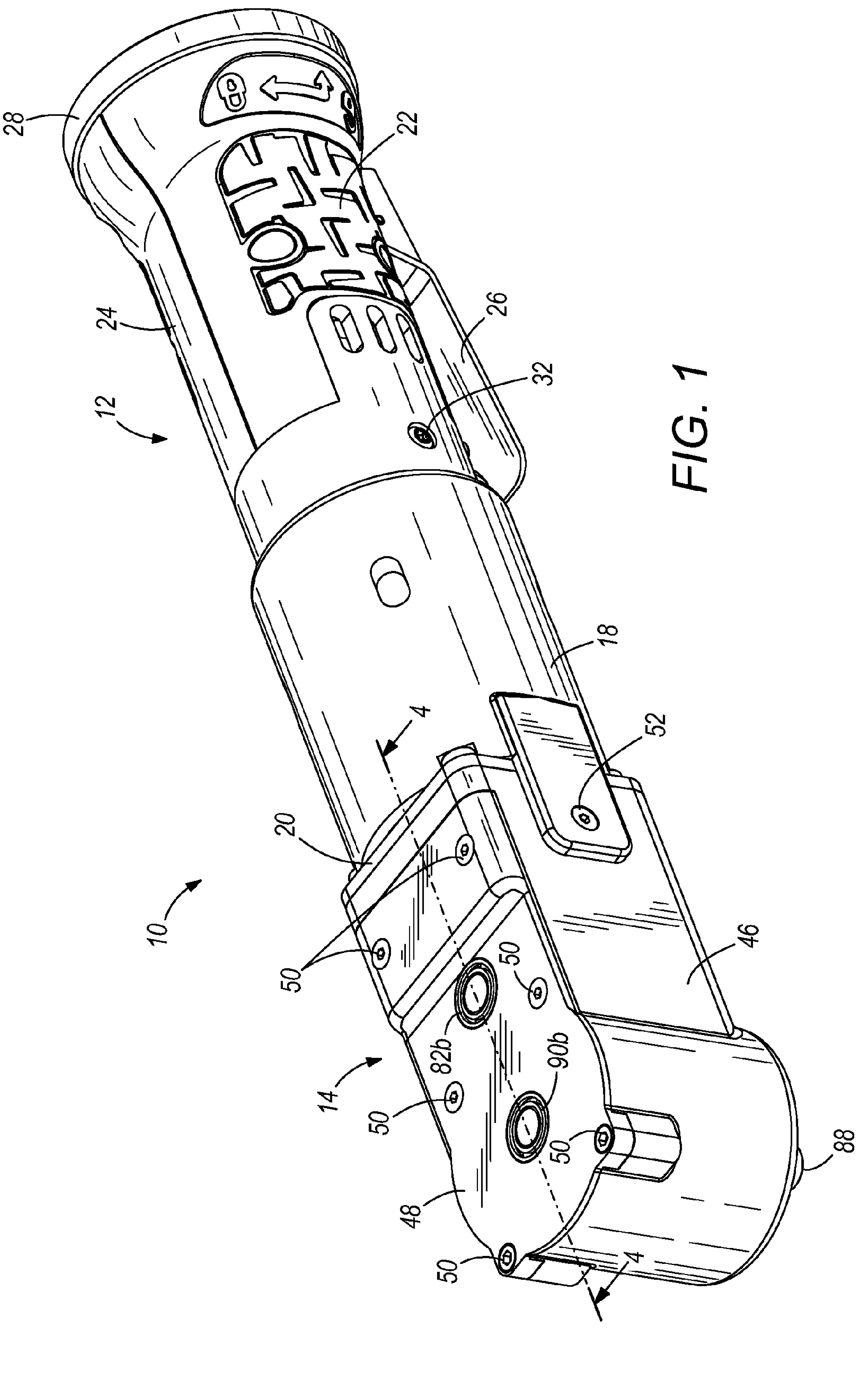

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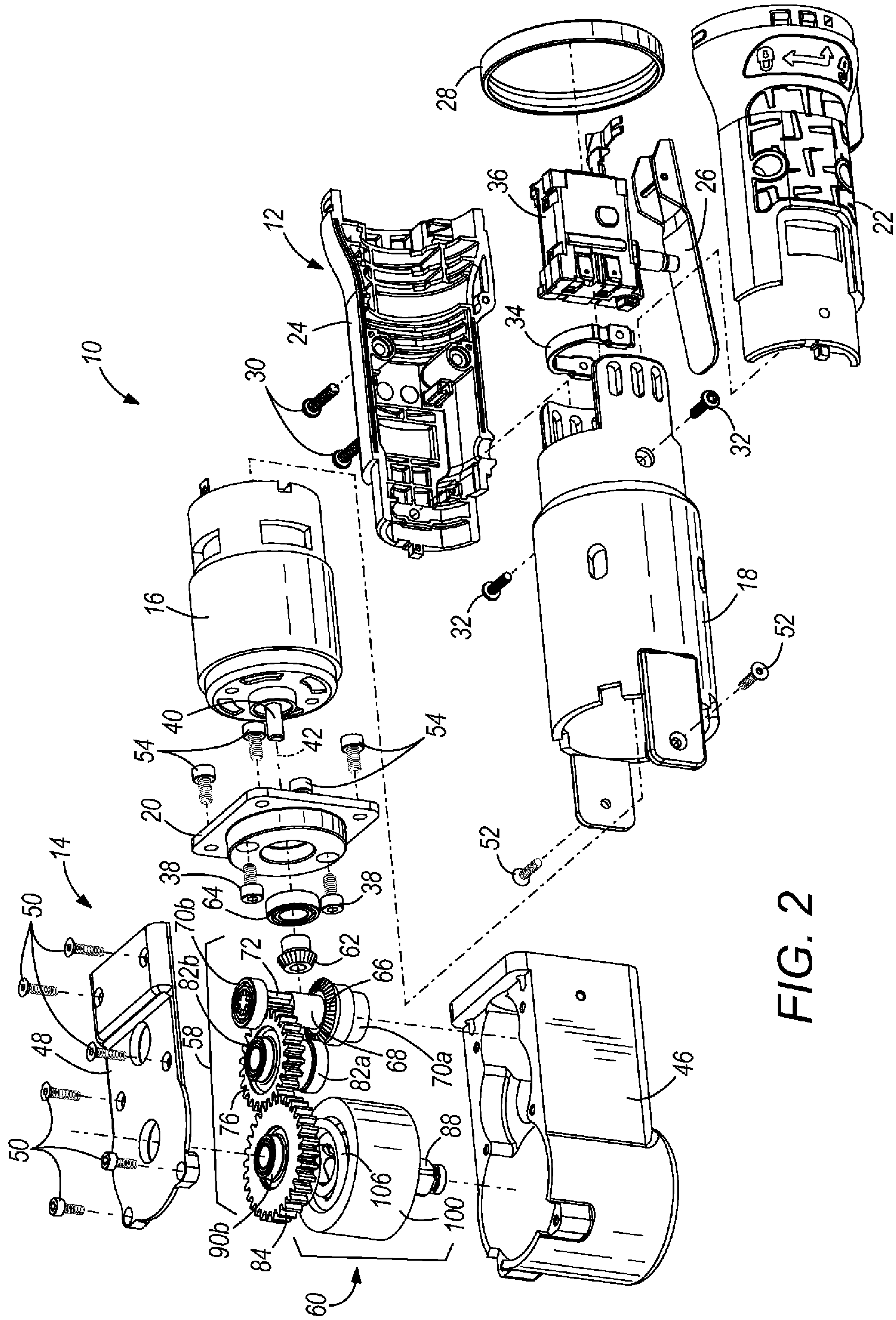
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FIG. 2

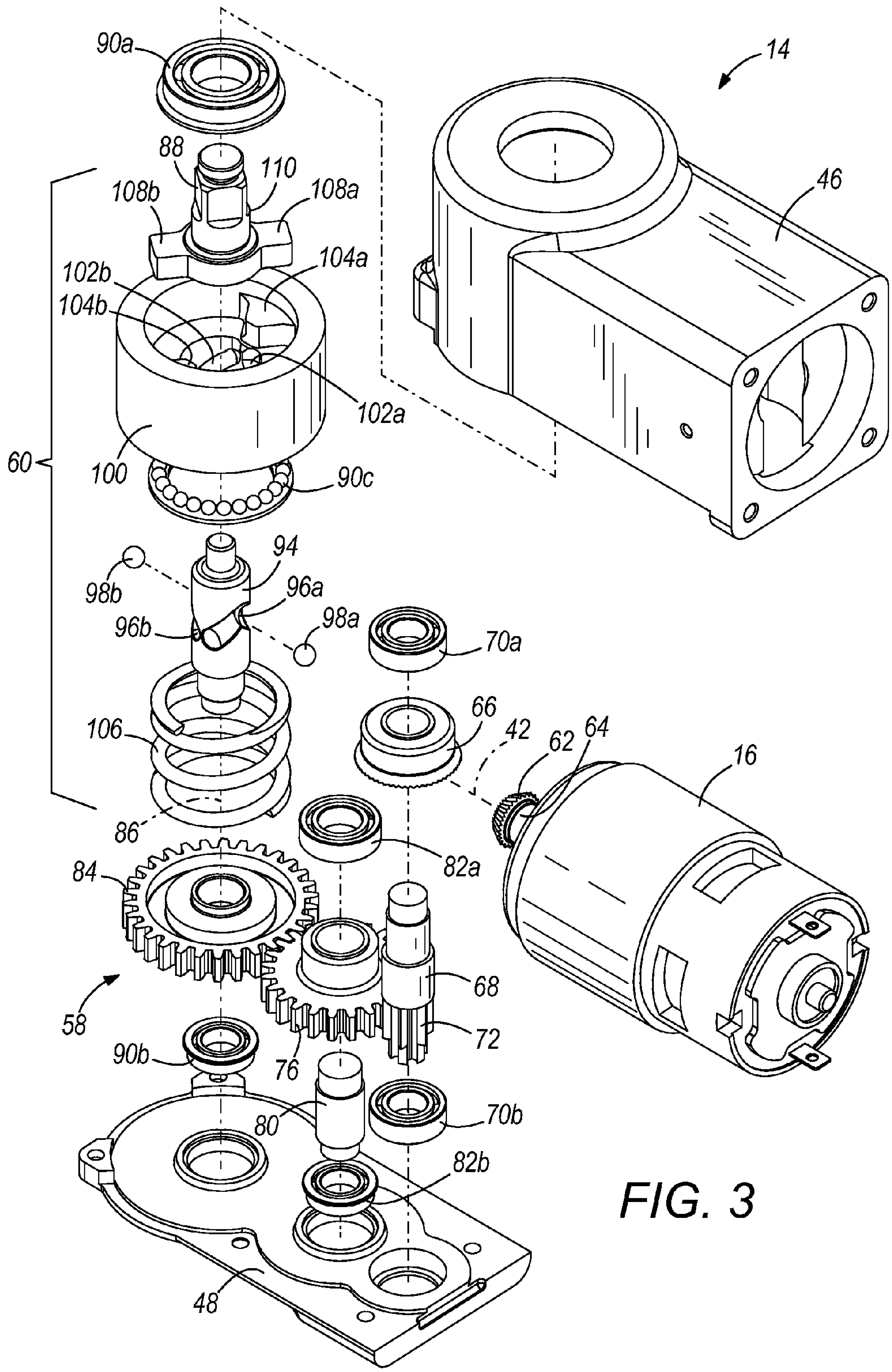

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FIG. 3

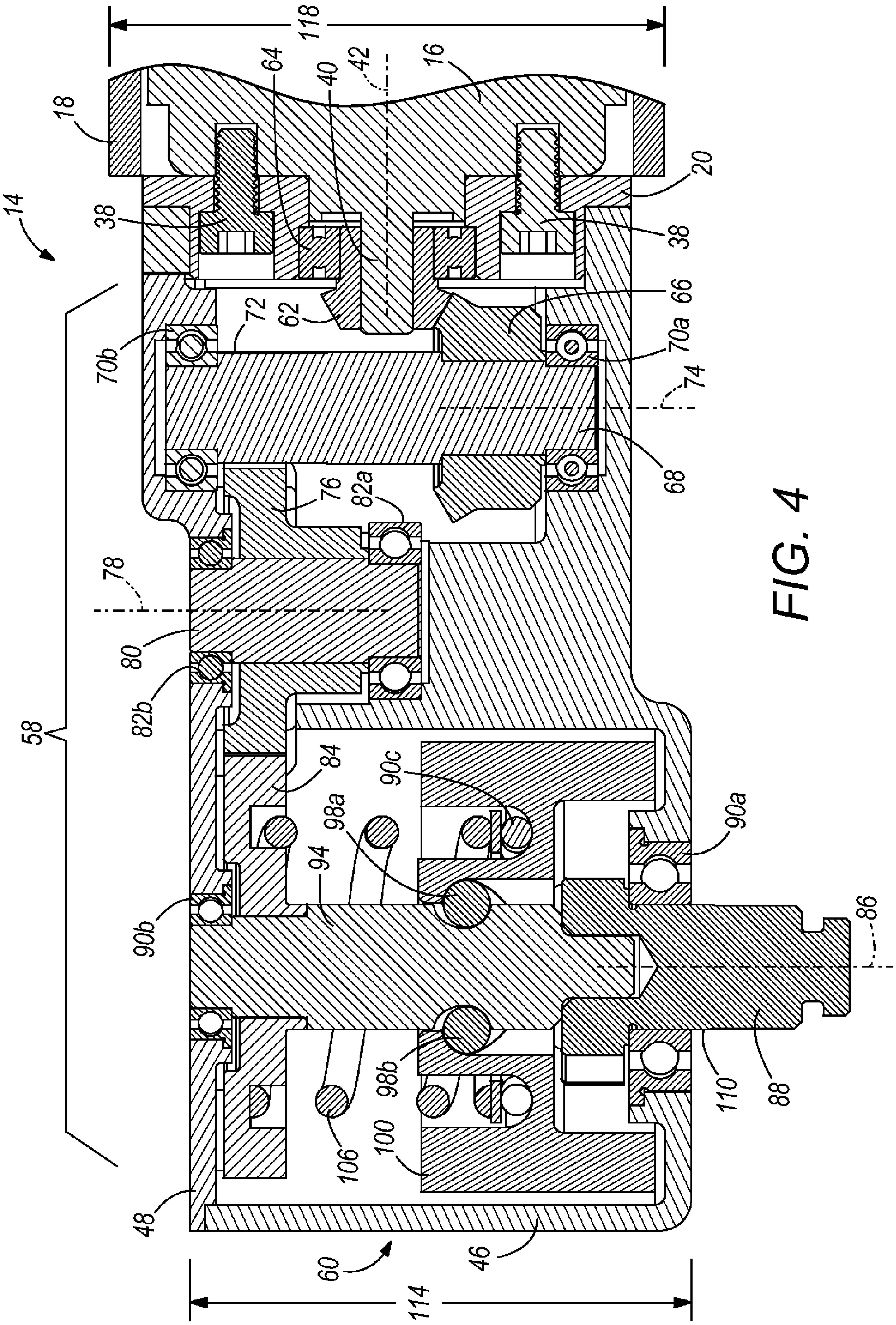
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FIG. 4

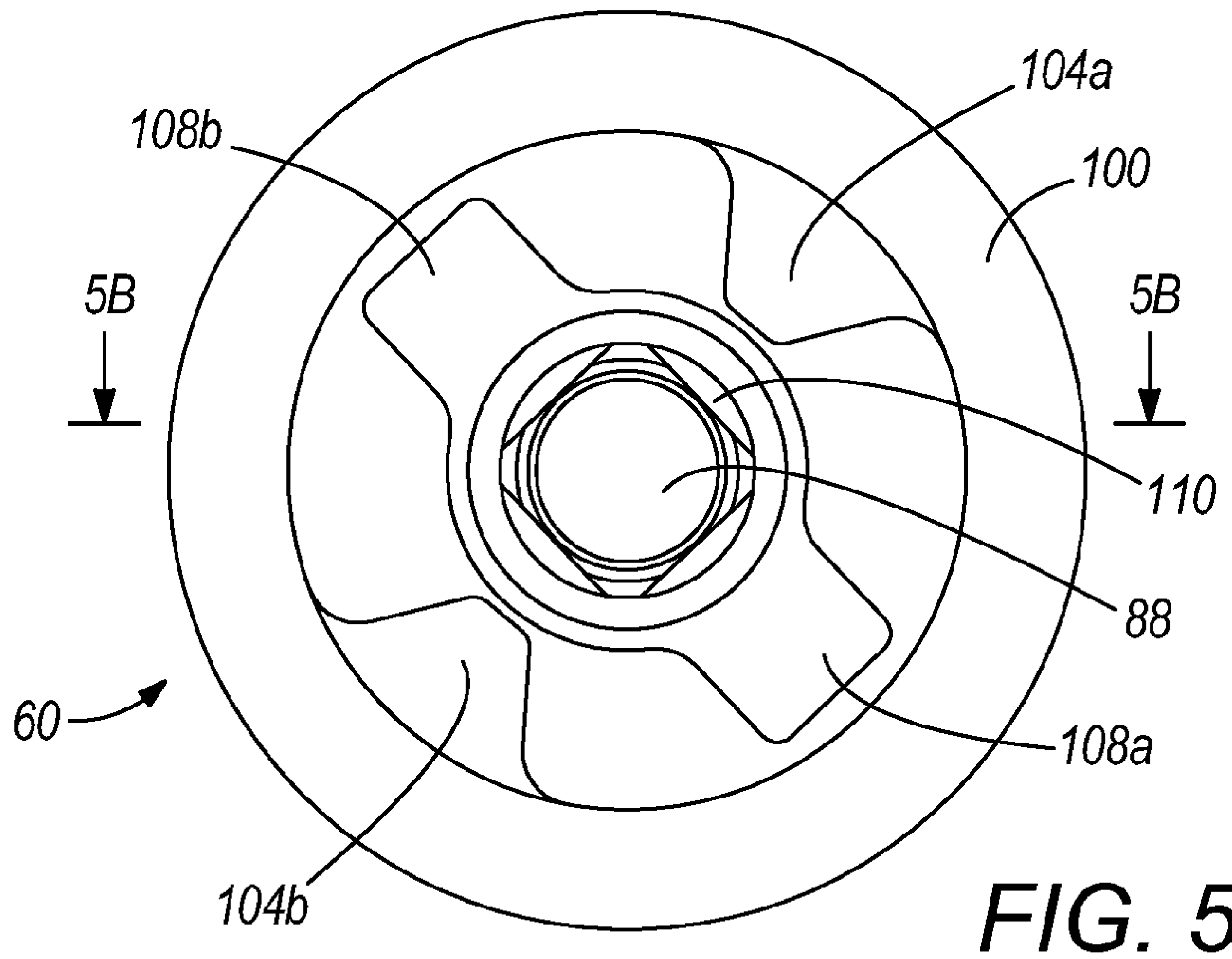

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FIG. 5A

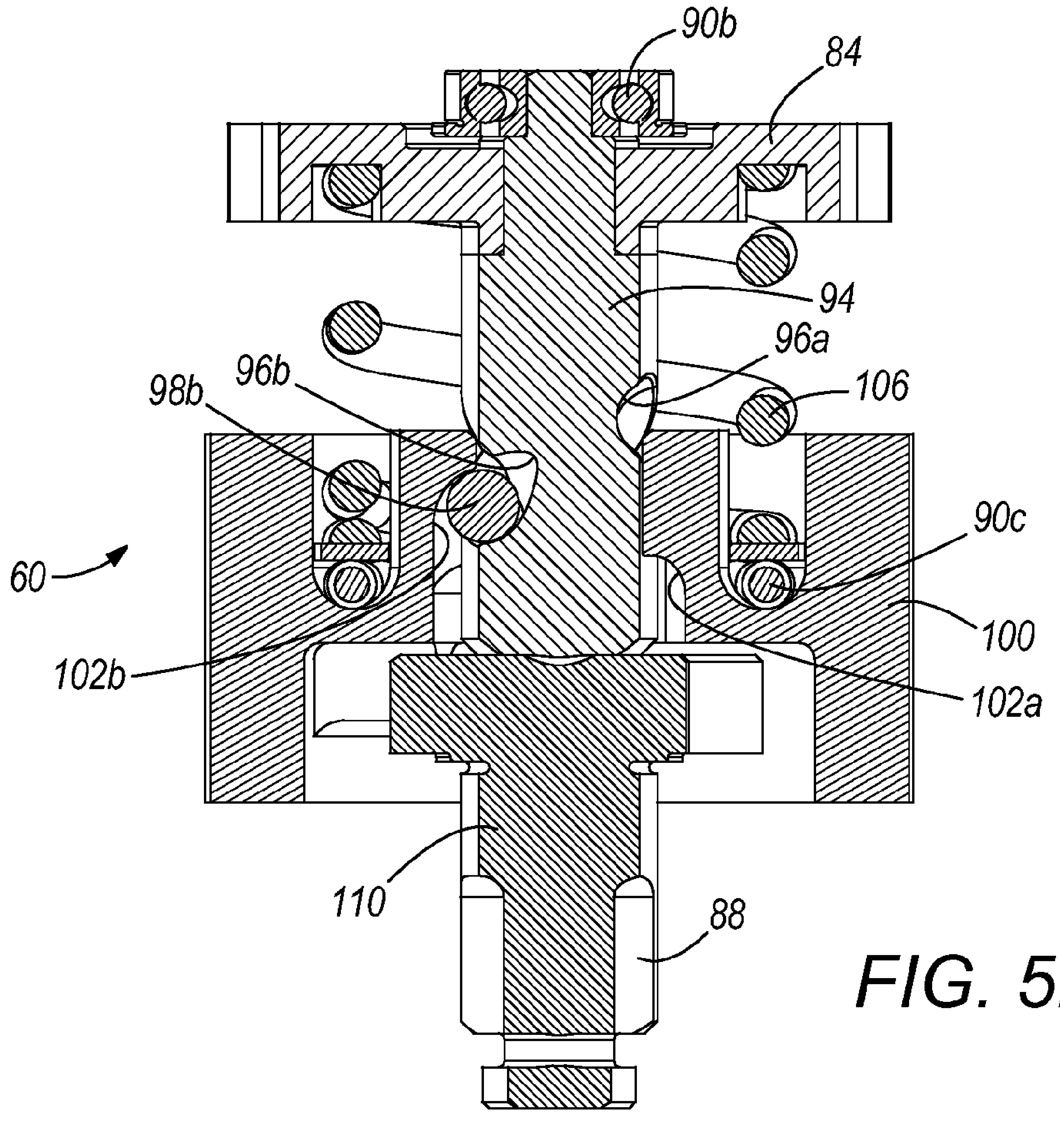

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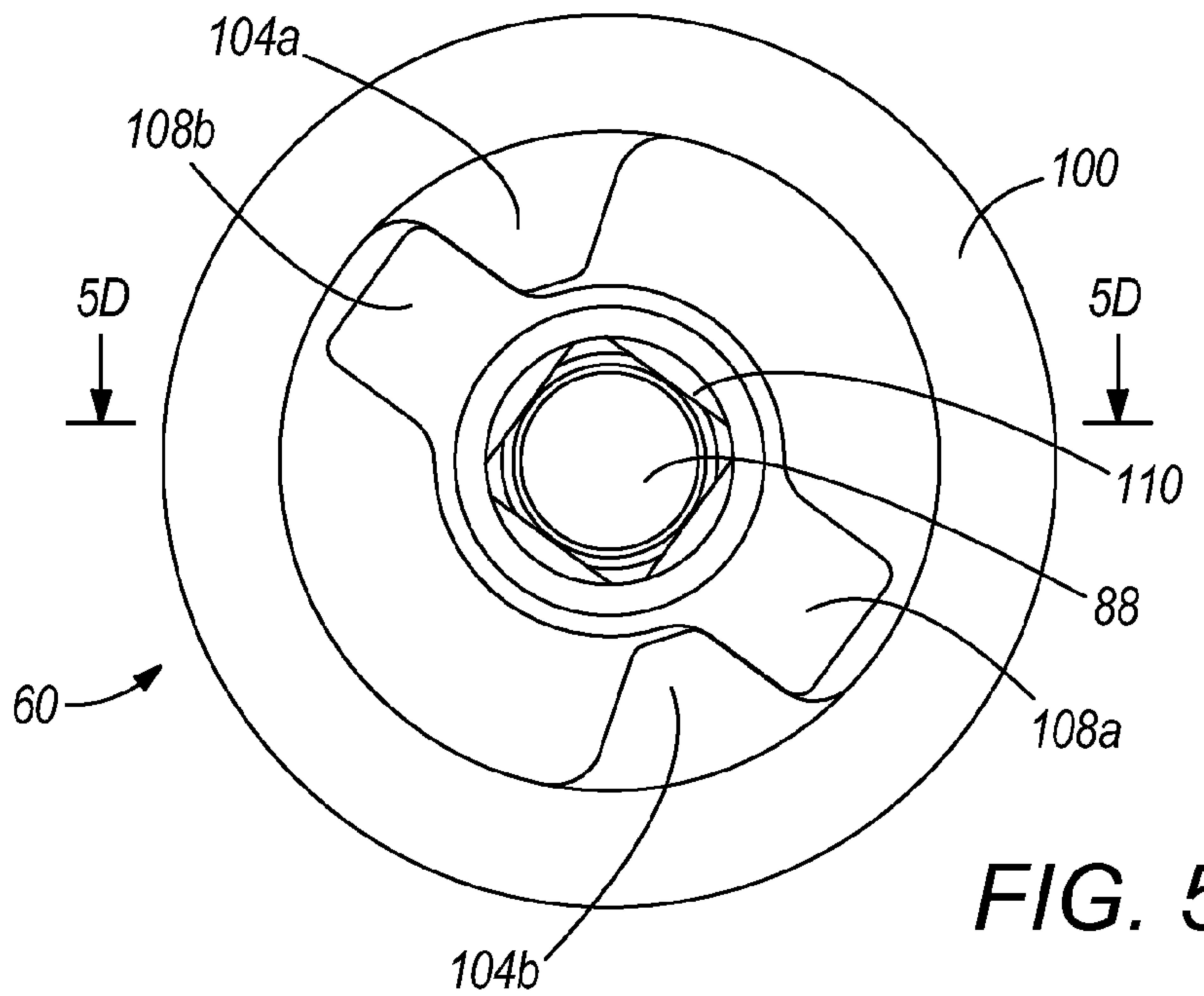
FIG. 5B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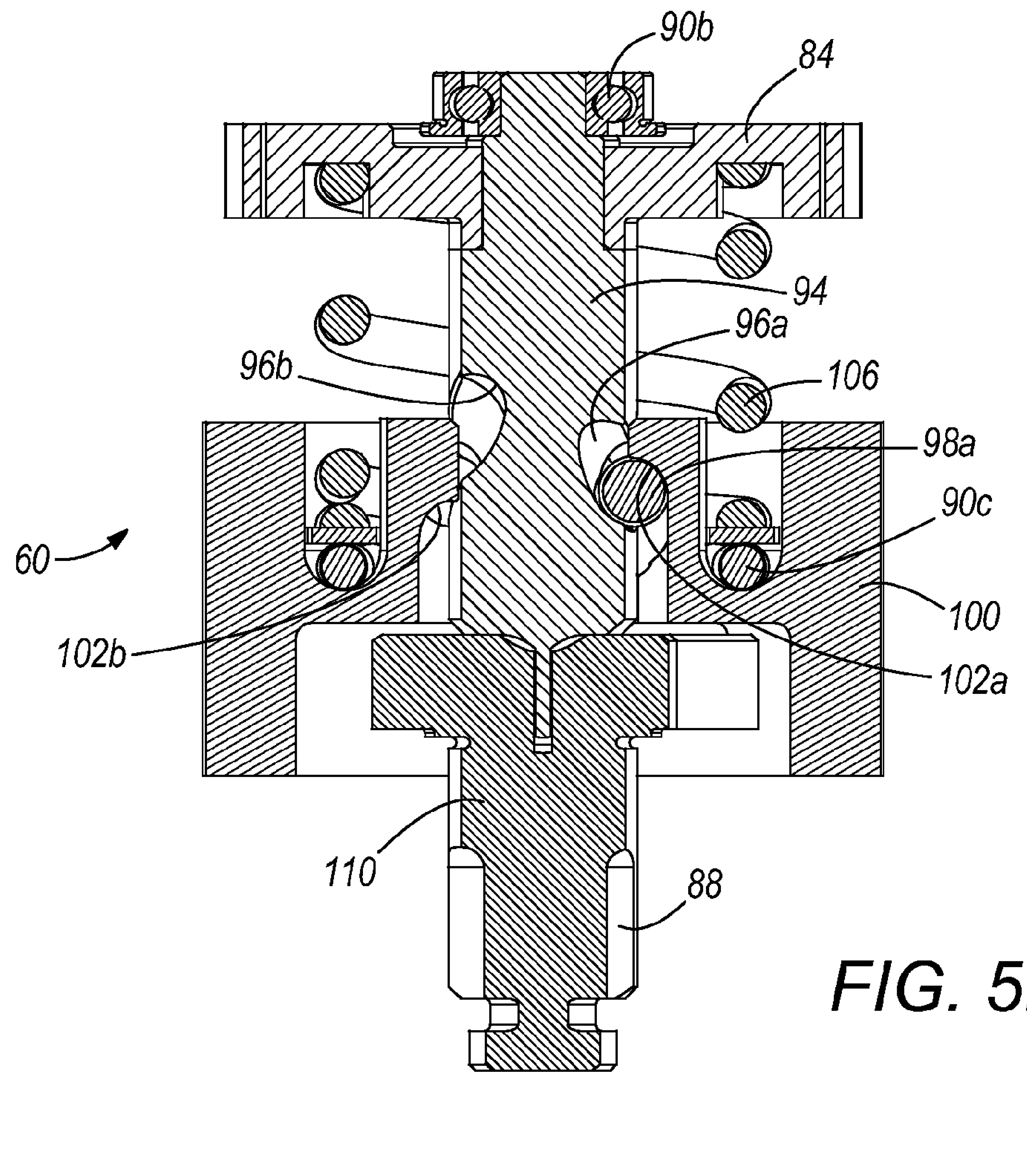
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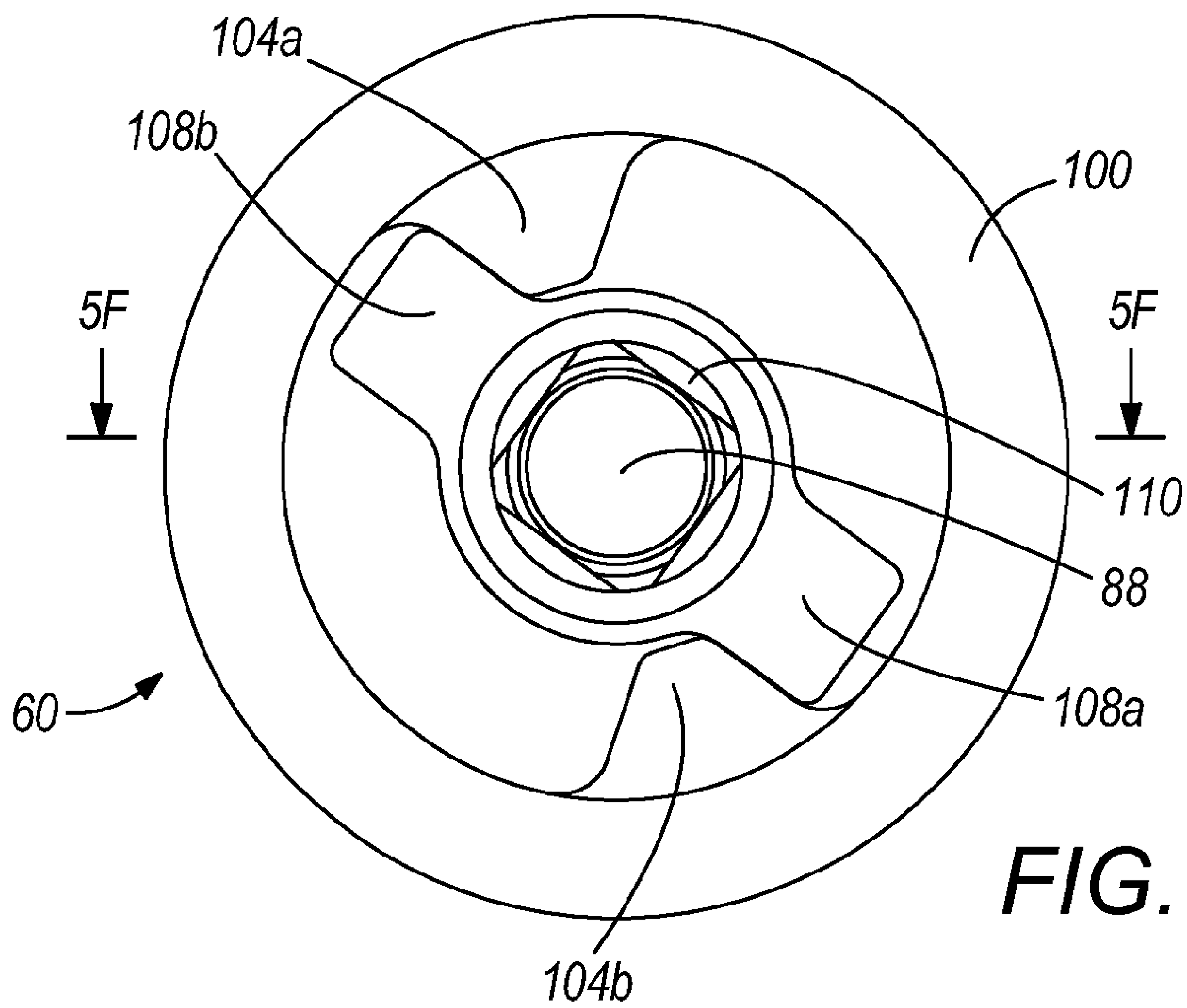
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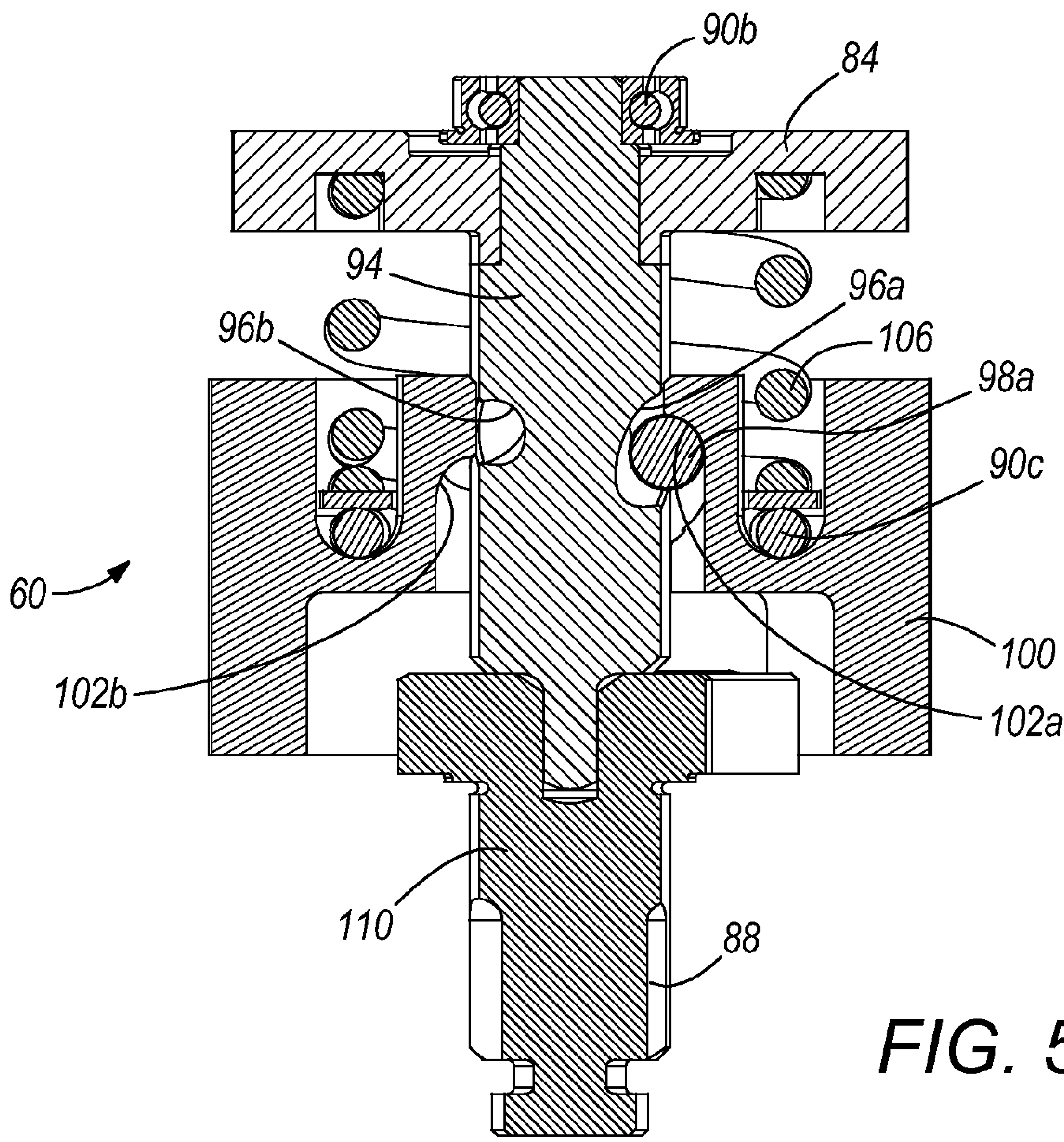
FIG. 5E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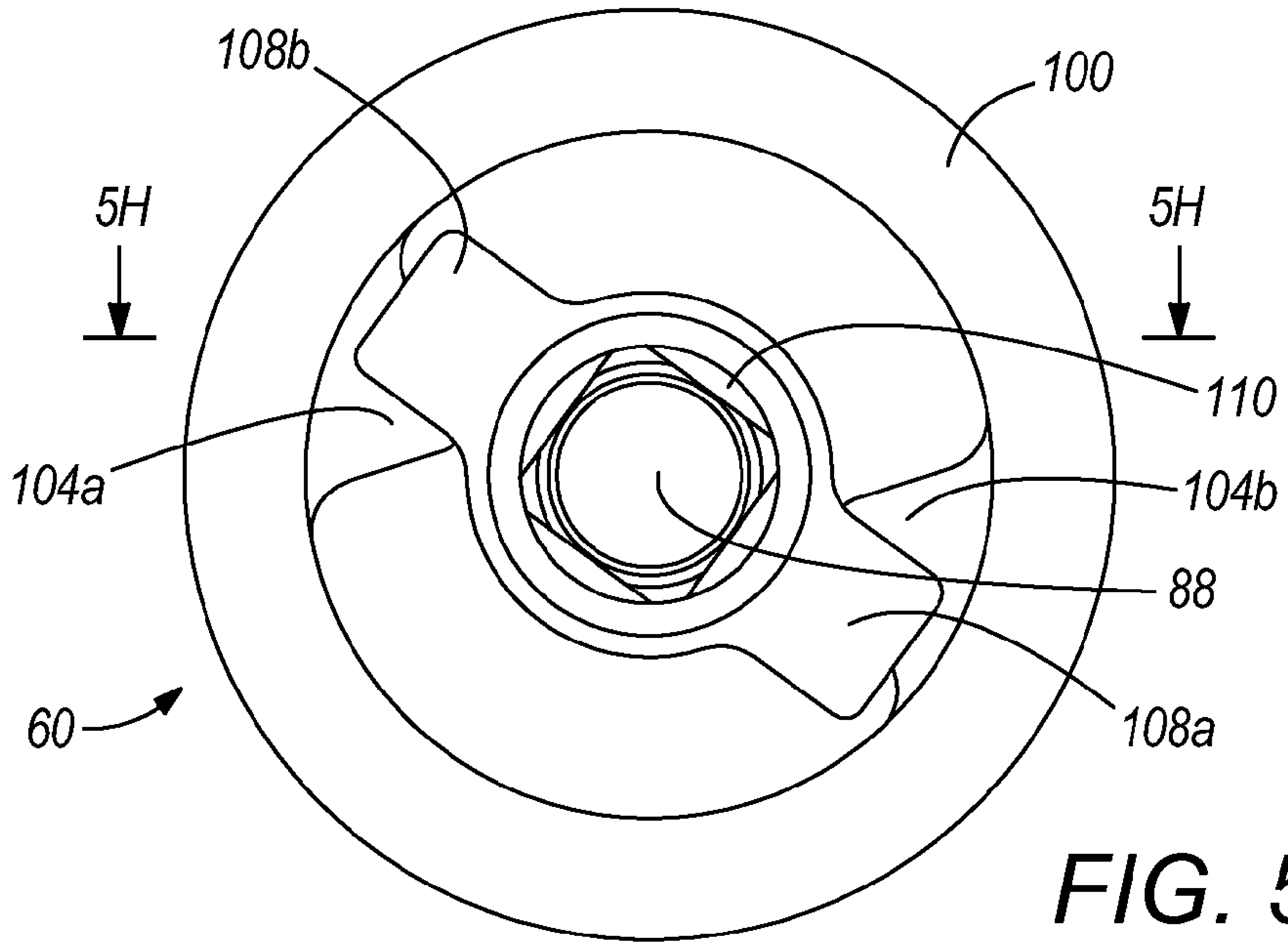
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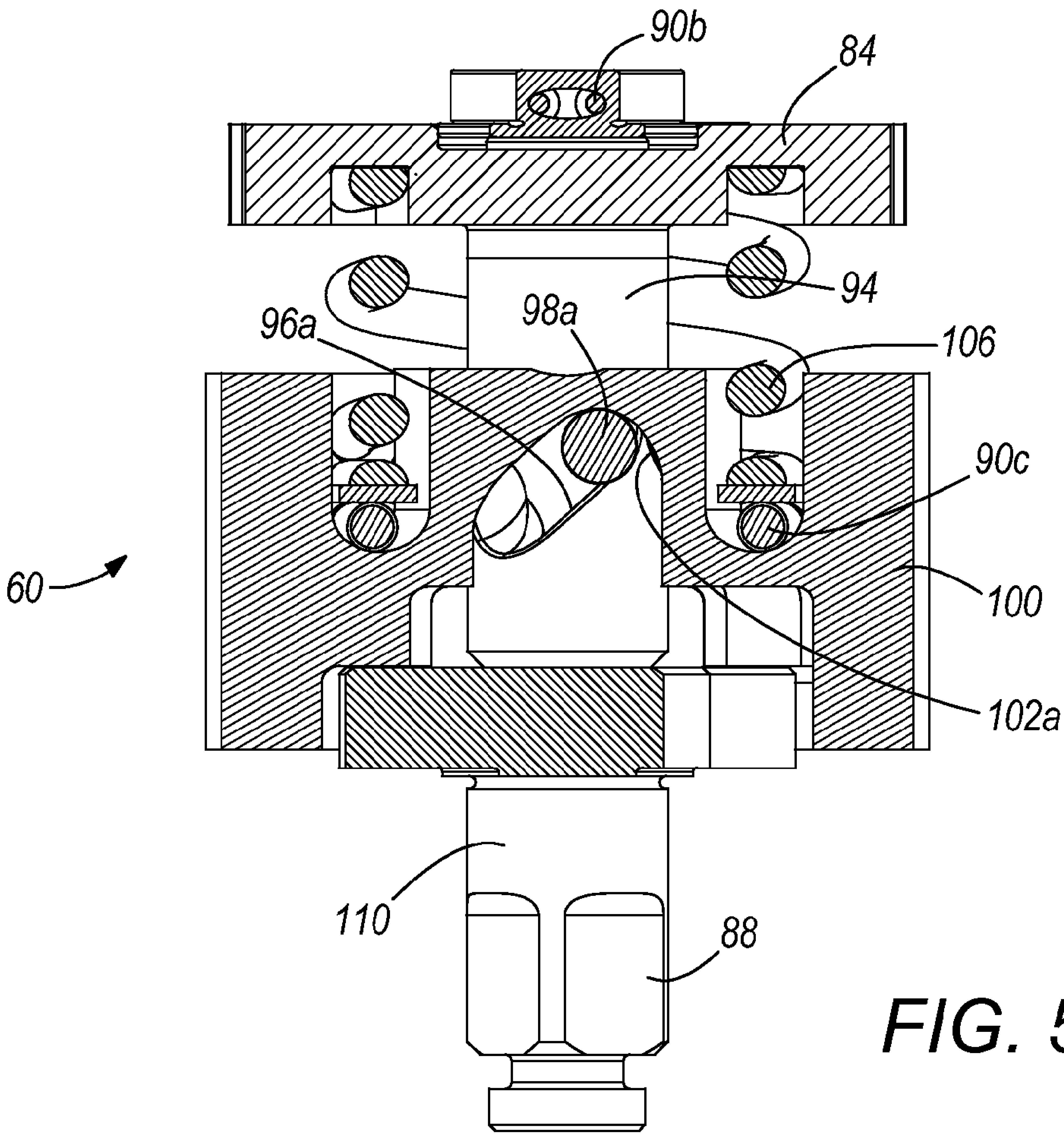
FIG. 5G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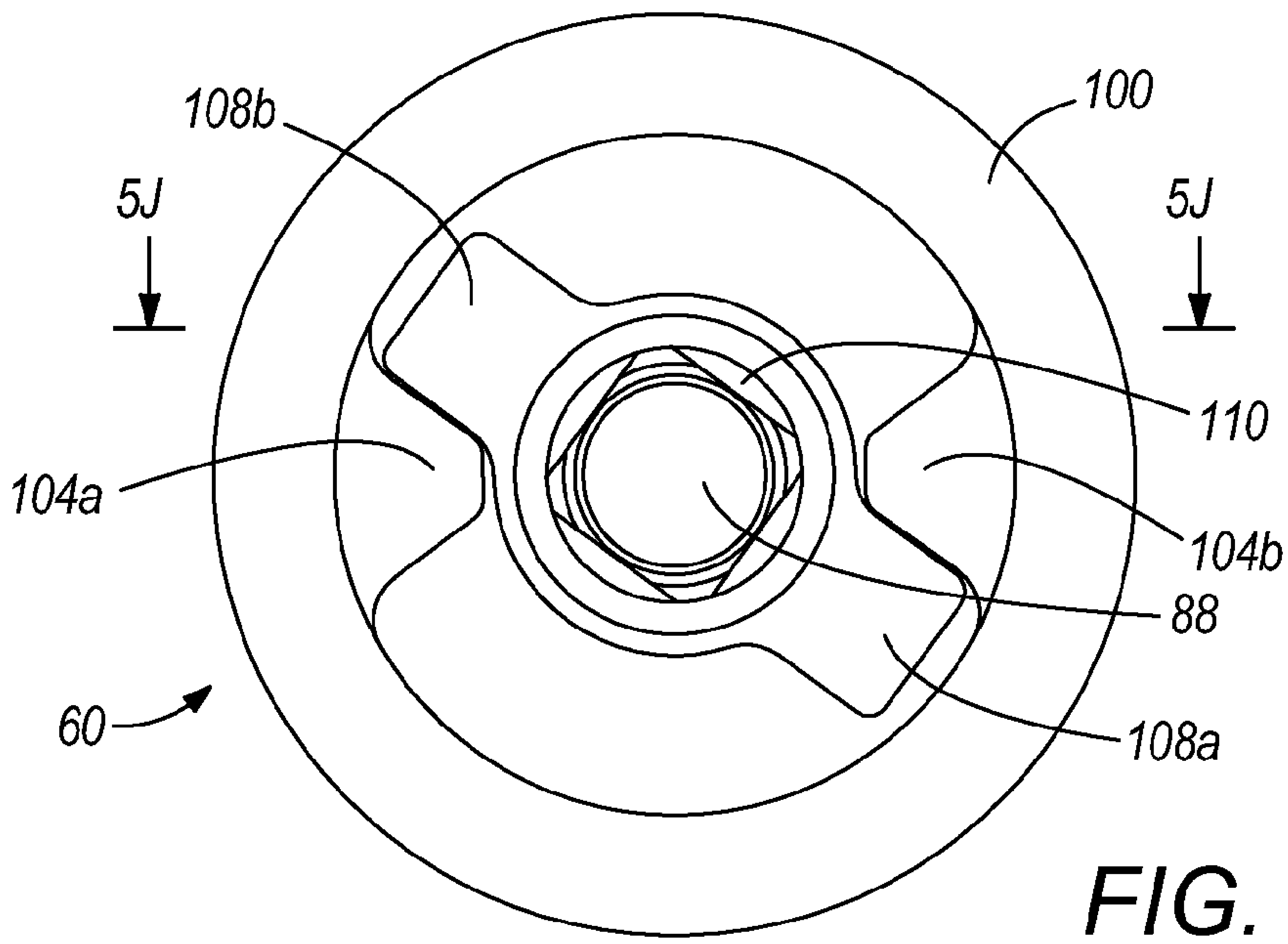
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FIG. 5I

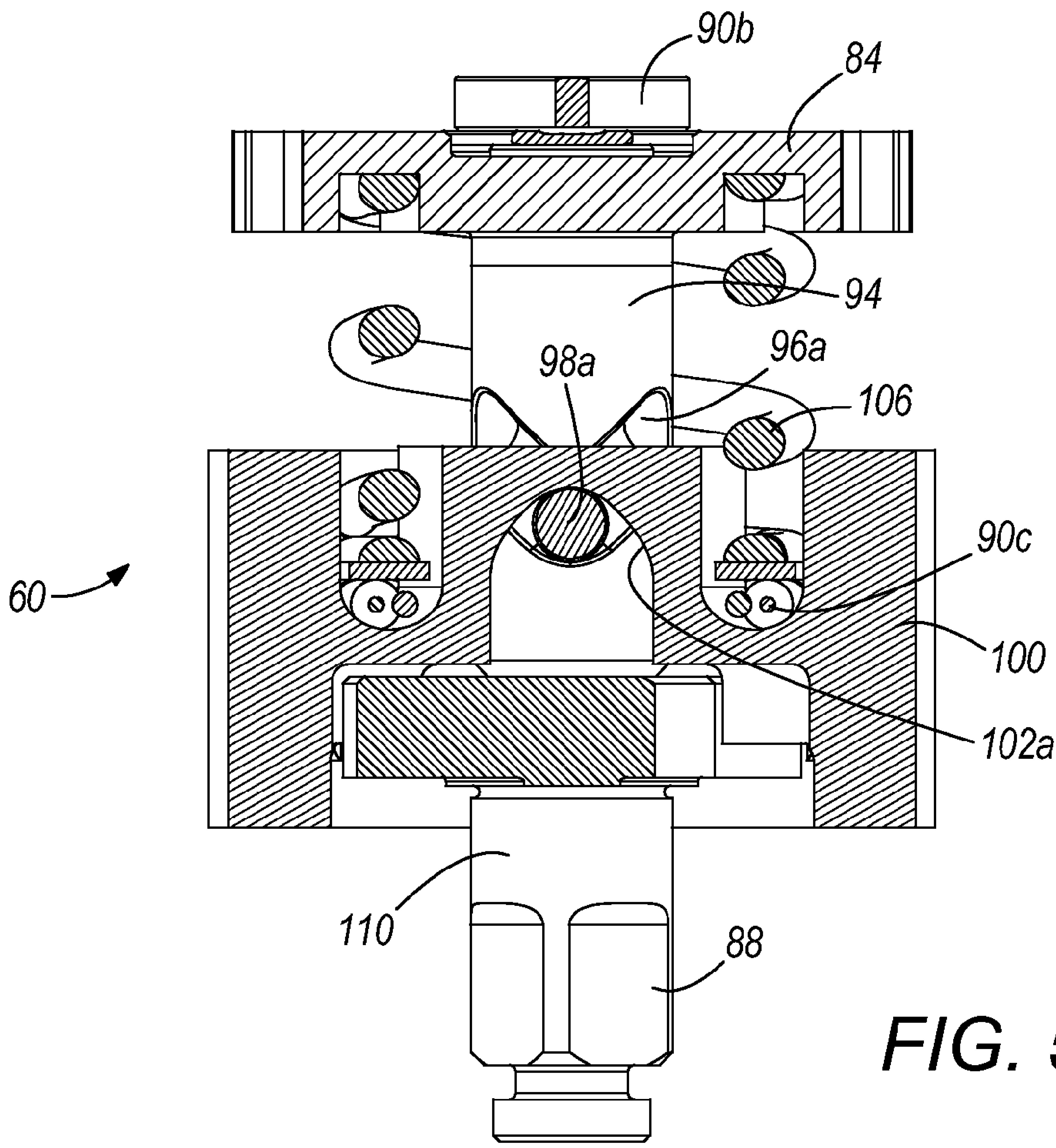
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FIG. 5J

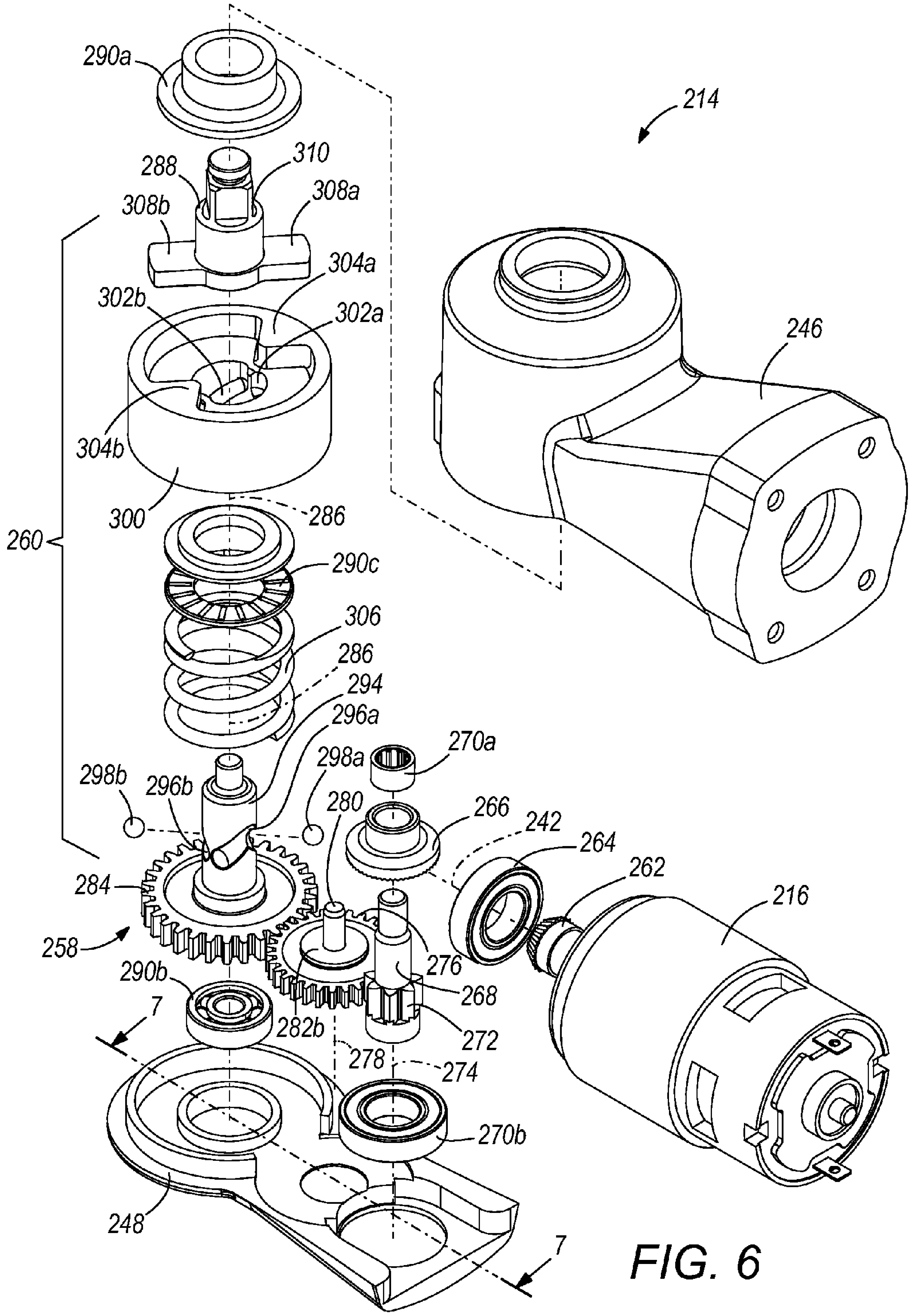
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FIG. 6

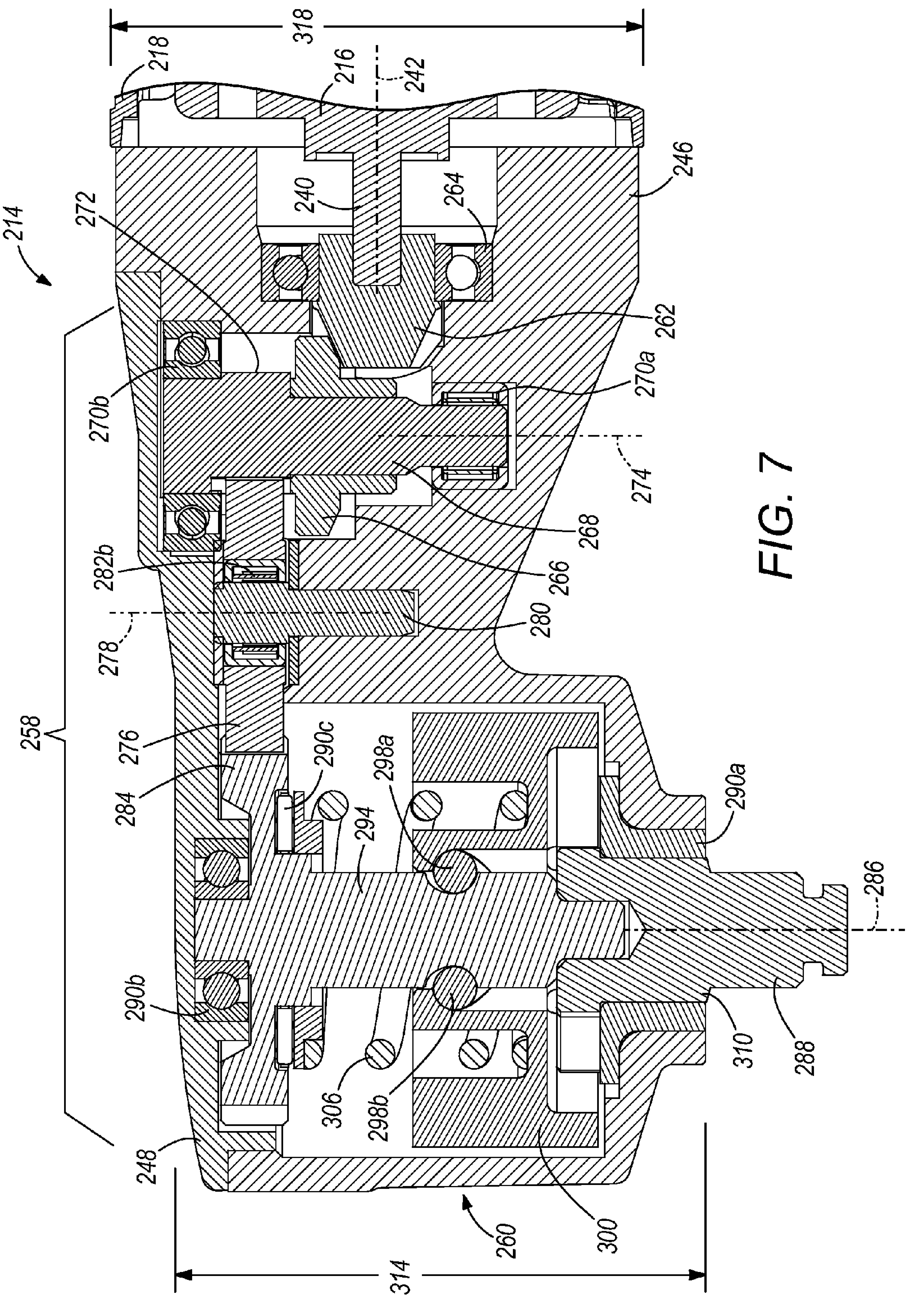
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FIG. 7

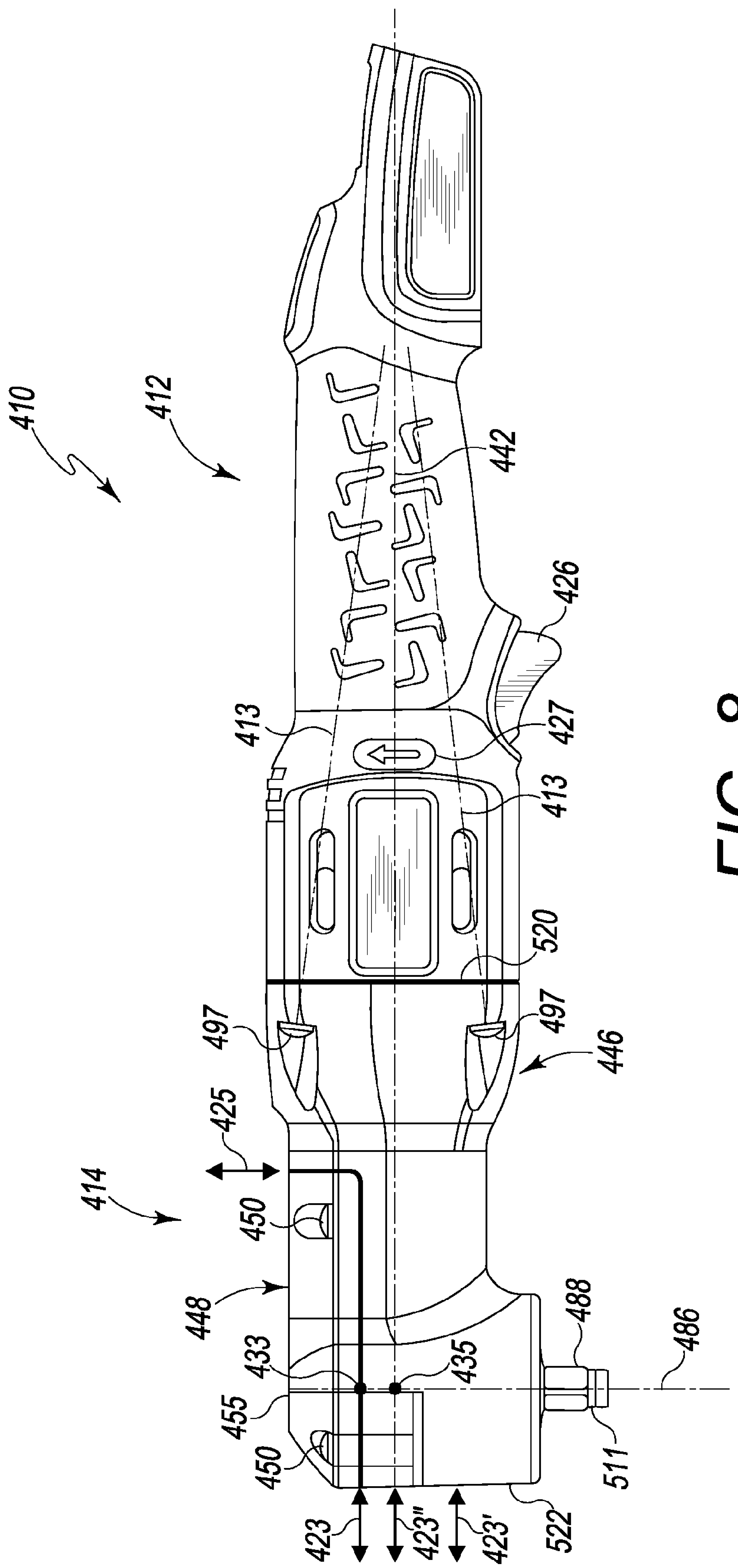
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FIG. 8

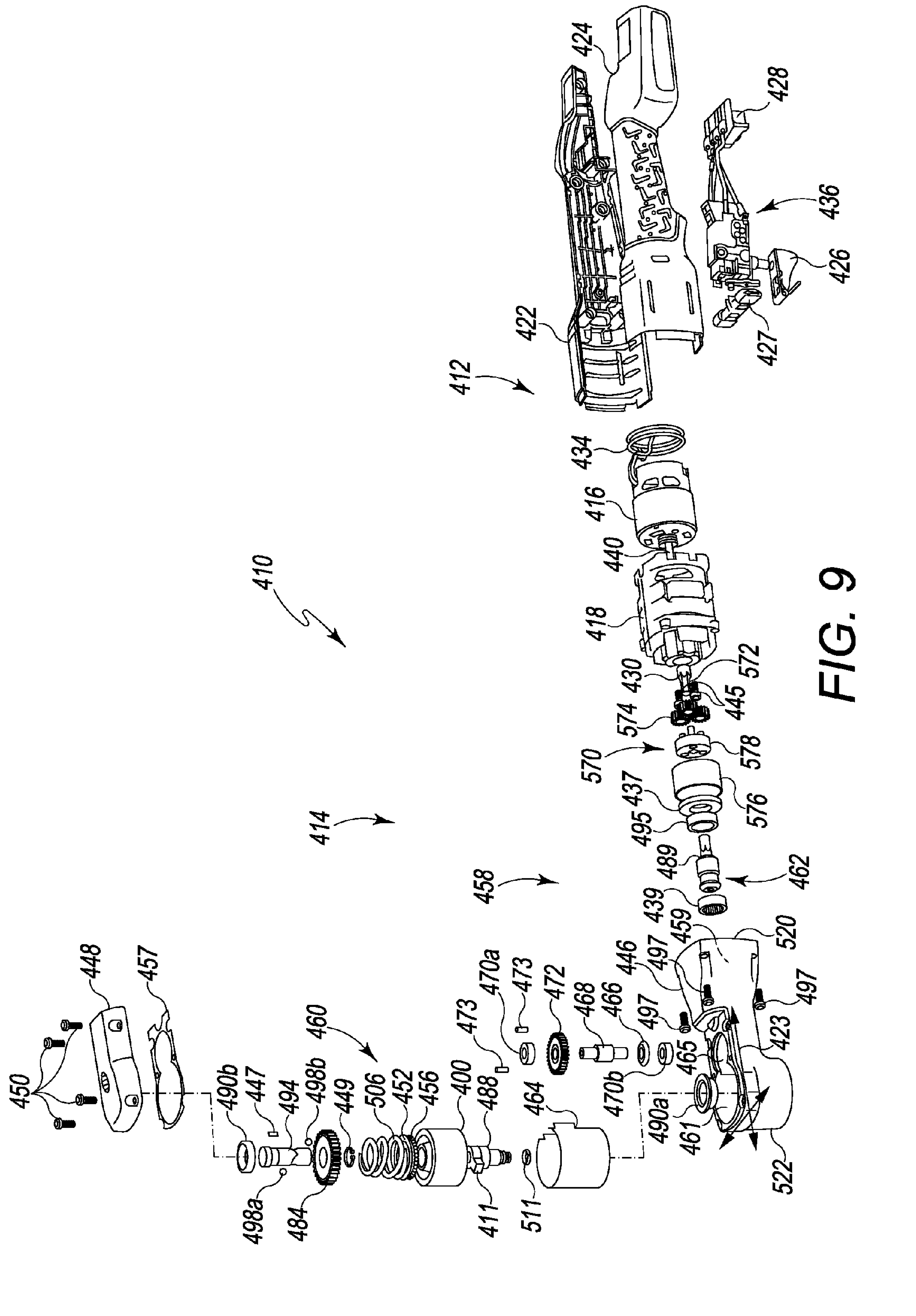
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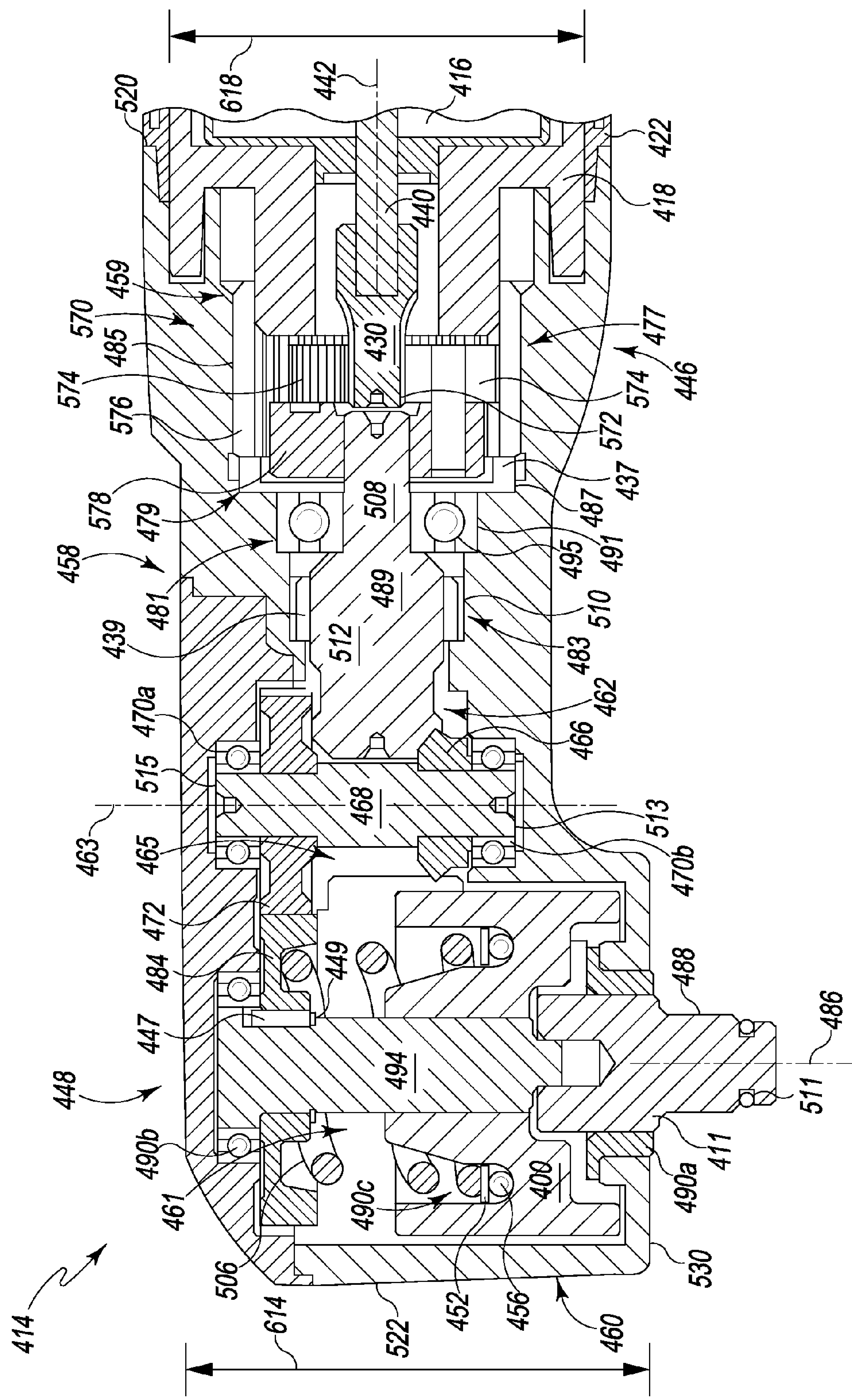
FIG. 9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411
490a
461
400
490c
506
530
614
522
452
456
460
414

FIG. 10

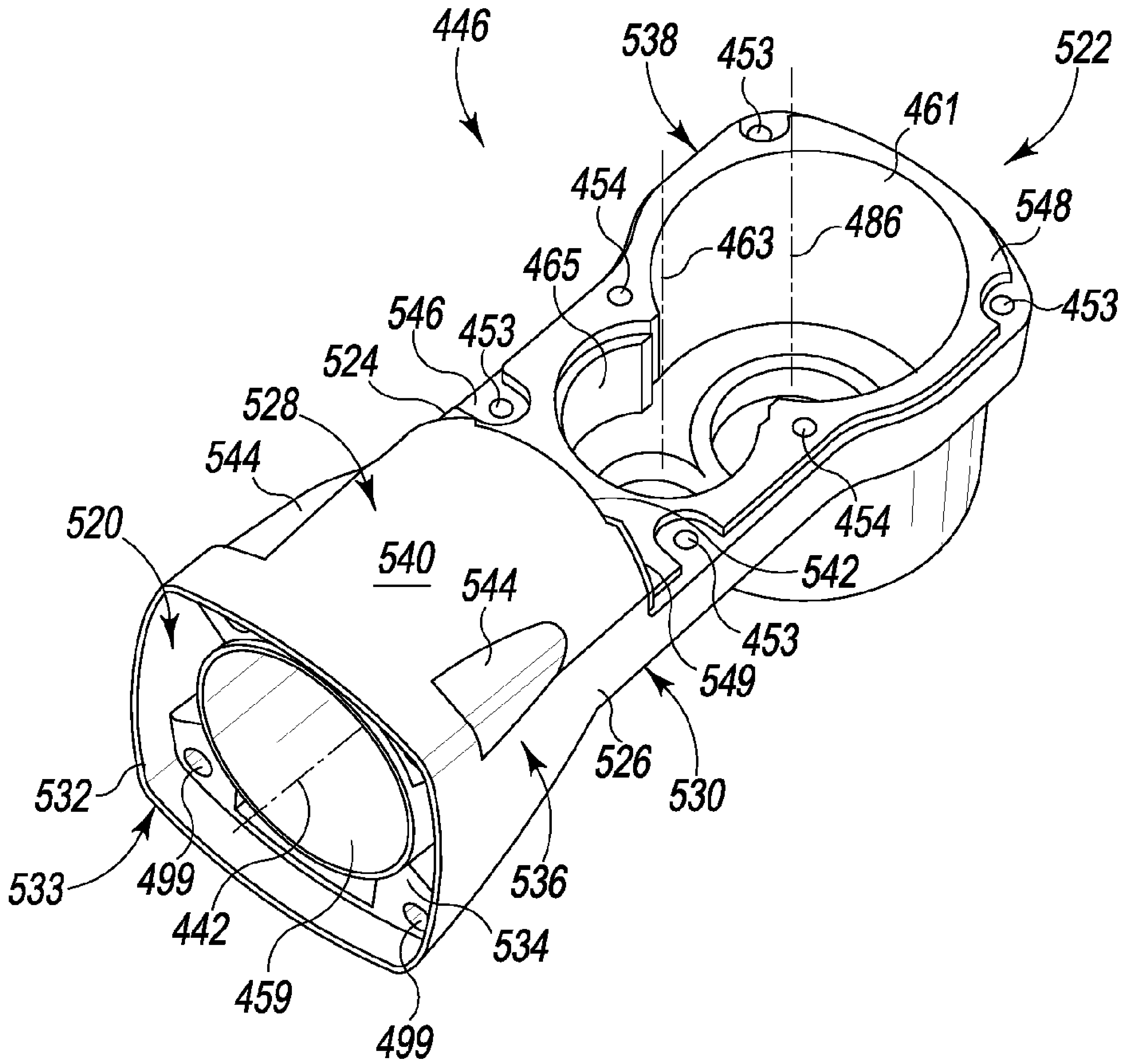
446
538
453
522
461
454
463
486
548
465
453
546
453
524
528
544
454
520
540
542
544
453
549
526
530
532
536
533
499
534
442
459
499

FIG. 11

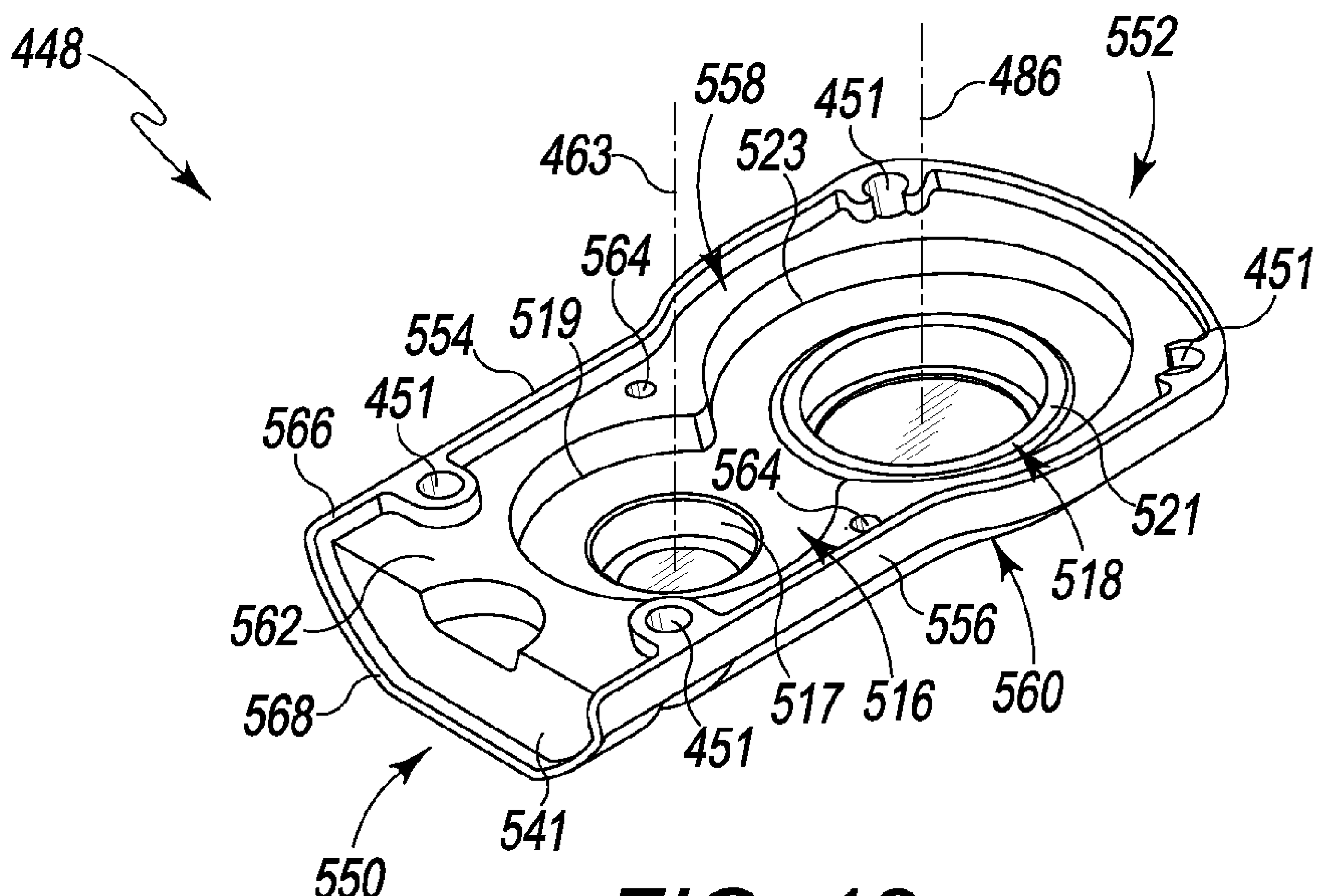
448
558
451
486
552
463
523
564
451
554
519
566
451
564
521
518
562
556
560
568
451
517
516
541
550

FIG. 12

ANGLE IMPACT TOOLS

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of U.S. patent application Ser. No. 13/033,241, filed Feb. 23, 2011 (entitled "Right Angle Impact Tool"), the entire disclosure of which is incorporated by reference herein.

TECHNICAL FIELD

The present disclosure relates, generally, to angle impact tools and, more particularly, to work attachment housings for such tools.

BACKGROUND

Many power tools that are used for tightening and loosening fasteners have difficulty fitting in tight spaces. In particular, existing impact tools may not be able to reach certain fasteners due to the size and/or orientation of the tool head and the output drive. In contrast, many tools that do fit in tight spaces may not be able to accomplish tightening and loosening of fasteners effectively and/or safely.

Various impact tools have been proposed in an attempt to address the foregoing concerns. Impact tools generally include a motor coupled to an impact mechanism that converts torque provided by the motor into a series of powerful rotary blows directed from one or more hammers to an anvil that is integrally formed with (or otherwise drives rotation of) an output drive of the impact tool. In angle impact tools, the output drive typically rotates about an output axis that is non-parallel to a motor axis about which an output shaft of the motor rotates.

The housing that supports the output drive, the impact mechanism, and other drive train components of existing angle impact tools has typically had a "clamshell" construction, in which the housing is partitioned into two sections along a parting plane that is parallel to both the output axis and the motor axis of the tool (e.g., a parting plane similar to the cross-section planes used in FIGS. **4**, **7**, and **10** of the present disclosure). However, this "clamshell" construction of the housing can result in poor alignment of the various drive train components, as well as difficulty in assembling and/or servicing the angle impact tool.

SUMMARY

According to one aspect, an angle impact tool may comprise a handle assembly extending along a first axis and supporting a motor, where the motor includes a shaft configured to rotate about a first axis, and a work attachment coupled to the handle assembly. The work attachment may comprise an impact mechanism including an anvil configured to rotate about a second axis that is non-parallel to the first axis and a hammer configured to rotate about the second axis to periodically deliver an impact load to the anvil to cause rotation of the anvil about the second axis, a gear assembly configured to transfer rotation from the shaft of the motor to the hammer of the impact mechanism, and a housing supporting the impact mechanism and the gear assembly. The housing may be partitioned along a first parting plane that is perpendicular to the second axis such that the housing includes a first housing section and a second housing section.

In some embodiments, the first axis may be parallel to the first parting plane. The first axis may lie in the first parting plane. In other embodiments, the first axis may be spaced apart from the first parting plane. The first axis may intersect the second axis between (i) a position of the anvil along the second axis and (ii) a point at which the second axis intersects the first parting plane. In other embodiments, the first parting plane may intersect the second axis between (i) a position of the anvil along the second axis and (ii) a point at which the second axis intersects the first axis. The first and second housing sections may also be partitioned along a second parting plane that is perpendicular to the first axis.

In some embodiments, the second housing section may be removably coupled to the first housing section by a plurality of fasteners. Each of the plurality of fasteners may extend through a corresponding aperture formed in the second housing section and may be received in a corresponding bore formed in the first housing section. Each of the corresponding apertures formed in the second housing section may be recessed from an exterior profile of the second housing section such that each of the plurality of fasteners that removably couples the second housing section to the first housing section does not extend beyond the exterior profile of the second housing section. The angle impact tool may further comprise a gasket positioned between the first and second housing sections to provide a fluid seal when the second housing section is removably coupled to the first housing section by the plurality of fasteners.

In some embodiments, the first housing section may be formed to include a first bore extending along the first axis, a second bore extending along the second axis, and a third bore extending along a third axis that is parallel to the second axis. The third bore may be positioned between the first and second bores and overlap both the first and second bores. The impact mechanism may be positioned in the second bore. The gear assembly may be positioned at least partially within the first and third bores. The second housing section may be formed to include a fourth bore extending along the second axis and a fifth bore extending along the third axis.

In some embodiments, the work attachment may further comprise a plurality of pins that each extend into a corresponding bore formed in the first housing section and into a corresponding bore formed in the second housing section, such that the plurality of pins align the fourth bore with the second bore and the fifth bore with the third bore. The first housing section may be formed to include a shoulder that protrudes toward the second housing section, and the second housing section may be formed to include a lip that protrudes toward the first housing section. The lip may engage the shoulder such that the fourth bore is aligned with the second bore and the fifth bore is aligned with the third bore.

In some embodiments, the gear assembly may include a first bevel gear positioned in the first bore of the first housing section and configured to rotate about the first axis and a second bevel gear positioned in the third bore of the first housing section and configured to rotate about the third axis, where the second bevel gear meshes with the first bevel gear. The first bore may comprise adjacent first and second bore sections. The second bore section may have a smaller diameter than the first bore section and may be located closer to the third bore than the first bore section. The first bore section may be bounded by a first internal surface of the first housing section, and the second bore section may be bounded by a second internal surface of the first housing section. The first bevel gear may include a shaft that extends along the first axis and comprises adjacent first and second shaft sections. The second shaft section may have a larger diameter than the first shaft section. The first shaft section may be positioned within the first bore section, and the second shaft section may be positioned within the second bore section. A bearing may support the first bevel gear for rotation about the first axis and engages both the first shaft section and the first internal surface. The bearing may abut both the second shaft section and the second internal surface to align the first and second bevel gears.

In some embodiments, the work attachment may be removably coupled to the handle assembly by a plurality of fasteners. Each of the plurality of fasteners may extend through a corresponding aperture formed in the first housing section and may be received in a corresponding bore formed in the handle assembly. Each corresponding bore extending along an axis may be disposed at an acute angle to the first axis.

According to another aspect, a work attachment may comprise a housing body configured to be coupled to a motorized tool including a rotatable output shaft, where the housing body is formed to include (i) a first bore extending along a first axis, (ii) a second bore extending along a second axis that is perpendicular to the first axis, and (iii) a third bore extending along a third axis that is perpendicular to the first axis, the third bore being positioned between the first and second bores and overlapping both the first and second bores. The work attachment may further comprise an impact mechanism received in the second bore of the housing body, the impact mechanism including a hammer configured to rotate about the second axis to periodically deliver an impact load to an anvil to cause rotation of the anvil about the second axis. The work attachment may further comprise a gear assembly received at least partially in the first and third bores of the housing body, where the gear assembly is configured to be coupled to the rotatable output shaft of the motorized tool such that rotation of the output shaft about the first axis drives rotation of the hammer about the second axis. The work attachment may further comprise a housing cap removably coupled to the housing body by a plurality of fasteners to enclose the second and third bores, where the housing cap abuts the housing body along a first parting plane that is perpendicular to the second and third axes.

In some embodiments, the housing cap may also abut the housing body along a second parting plane that is perpendicular to the first axis. The second parting plane may be located between the third axis and an end of the housing body configured to be coupled to the motorized tool.

BRIEF DESCRIPTION OF THE DRAWINGS

The concepts described in the present disclosure are illustrated by way of example and not by way of limitation in the accompanying figures. For simplicity and clarity of illustration, elements illustrated in the figures are not necessarily drawn to scale. For example, the dimensions of some elements may be exaggerated relative to other elements for clarity. Further, where considered appropriate, reference labels have been repeated among the figures to indicate corresponding or analogous elements. The detailed description particularly refers to the accompanying figures in which:

FIG. **1** is a perspective view of one illustrative embodiment of an angle impact tool;

FIG. **2** is an exploded view of the angle impact tool of FIG. **1**;

FIG. **3** is an exploded view of a work attachment of the angle impact tool of FIG. **1**;

FIG. **4** is a cross-sectional view of the work attachment of FIG. **3**, taken along line **4-4** in FIG. **1**;

FIGS. **5**A-**5**J illustrate an impact cycle of the angle impact tool of FIGS. **1-4**;

FIG. **6** is an exploded view of another illustrative embodiment of a work attachment for an angle impact tool;

FIG. **7** is a cross-sectional view of the work attachment of FIG. **6**, taken along line **7-7** in FIG. **6**;

FIG. **8** is a side elevation view of yet another illustrative embodiment of an angle impact tool including a work attachment;

FIG. **9** is an exploded view of the angle impact tool of FIG. **8**;

FIG. **10** is a cross-sectional view of the work attachment of the angle impact tool of FIG. **8**, taken along a similar line to the cross-sectional views of FIGS. **4** and **7**;

FIG. **11** is a perspective view of a housing body of the work attachment of the angle impact tool of FIG. **8**; and

FIG. **12** is a perspective view of a housing cap of the work attachment of the angle impact tool of FIG. **8**.

DETAILED DESCRIPTION OF THE DRAWINGS

While the concepts of the present disclosure are susceptible to various modifications and alternative forms, specific exemplary embodiments thereof have been shown by way of example in the drawings and will herein be described in detail. It should be understood, however, that there is no intent to limit the concepts of the present disclosure to the particular forms disclosed, but on the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the present disclosure. Unless otherwise specified, the terms “coupled,” “mounted,” “connected,” “supported,” and variations thereof are used broadly and encompass both direct and indirect couplings, mountings, connections, and supports.

Referring now to FIGS. **1-4**, one illustrative embodiment of an angle impact tool **10** that includes a handle assembly **12** and a work attachment **14** is shown. The illustrated handle assembly **12** includes a motor **16**, a motor housing **18**, a motor bracket **20**, a handle housing section **22**, a handle housing section **24**, a trigger lever **26**, and a lock ring **28**. The lock ring **28** and a plurality of fasteners **30** retain the two handle housing sections **22**, **24** together. The motor housing **18** is coupled to the handle housing sections **22**, **24** by a plurality of fasteners **32** and a U-shaped part **34**. A switch **36** is included in the handle assembly **12** between the handle housing sections **22**, **24**. The switch **36** is coupled (mechanically and/or electrically) to the trigger lever **26**, such that actuation of the trigger lever **26** causes actuation of the switch **36** and, therefore, operation of the motor **16**.

The motor bracket **20** is coupled to the motor **16** by a plurality of fasteners **38**. The motor **16** includes an output shaft, such as the illustrated rotor **40**, that is rotatable about a longitudinal handle axis **42**. The illustrated motor **16** is an electric motor, but any suitable prime mover (such as the pneumatic motor disclosed in U.S. Pat. No. 7,886,840, the entire disclosure of which is incorporated by reference herein) may be utilized. Although not shown in FIGS. **1-4**, a battery and a directional reverse switch may be provided on the angle impact tool **10**, in some embodiments.

The illustrated work attachment **14** includes a housing **46**, **48** that is partitioned into two sections, namely, a housing body **46** and a housing cap **48**. As described in greater detail below (with reference to the illustrative embodiment of FIGS. **8-12**), the housing **46**, **48** is partitioned along a parting plane that is perpendicular to an output axis **86** of the work attachment **14**. A plurality of fasteners **50** removably couple the housing cap **48** to the housing body **46**. The motor housing **18** is coupled to the housing body **46** with a plurality of fasteners **52**. The motor bracket **20** is coupled to the housing body **46** by a plurality of fasteners **54**.

The housing **46**, **48** of the illustrated work attachment **14** supports a gear assembly **58** and an impact mechanism **60**. In the illustrative embodiment of FIGS. **1-4**, the gear assembly **58** includes a bevel gear set comprising a bevel gear **62** and a bevel gear **66**. The bevel gear **62** is coupled to the rotor **40** for rotation with the rotor **40** about the longitudinal handle axis **42**. A bearing **64** is positioned between the bevel gear **62** and the motor bracket **20**. The bevel gear **66** meshes with the bevel gear **62**. The bevel gear **66** is coupled to a shaft **68** for rotation with the shaft **68** about an axis **74** (FIG. **4**). The shaft **68** is supported in the housing **46**, **48** of the work attachment **14** by bearings **70***a*, **70***b*. The shaft **68** includes a splined portion **72** near bearing **70***b*. The splined portion **72** functions as a spur gear and, in some embodiments, can be replaced with a spur gear.

In the illustrative embodiment of FIGS. **1-4**, the gear assembly **58** also includes a spur gear set comprising the splined portion **72** of the shaft **68**, an idler spur gear **76**, and a drive spur gear **84**. Rotation of the splined portion **72** of the shaft **68** causes rotation of the idler spur gear **76** about an axis **78** (FIG. **4**). The idler spur gear **76** is coupled to a shaft **80** for rotation with the shaft **80** about the axis **78**. The shaft **80** is supported in the housing **46**, **48** of the work attachment **14** by bearings **82***a*, **82***b*.

The idler spur gear **76** meshes with a drive spur gear **84** to cause rotation of the drive spur gear **84** about the axis **86** (FIG. **4**). The drive spur gear **84** is coupled to an output drive **88** through the impact mechanism **60** for selectively rotating the output drive **88**. The drive spur gear **84** and the output drive **88** are supported for rotation within the housing **46**, **48** by bearings **90***a*, **90***b*, **90***c*. The output drive **88** is illustratively embodied as a square drive that may be connected to a socket or other fastener-driving output element.

In the illustrative embodiment of FIGS. **1-4**, the axes **74**, **78**, and **86** are all parallel to each other and are all perpendicular to the axis **42**. It is contemplated that, in other embodiments, one or more of the axes **74**, **78**, and **86** may be oriented at another angle that is non-parallel to the axis **42**.

The impact mechanism **60** may be embodied as any type of impact mechanism. In the illustrative embodiment of FIGS. **1-4**, the impact mechanism **60** is a ball-and-cam-type impact mechanism. The impact mechanism **60** includes a cam shaft **94** coupled to the drive spur gear **84** for rotation with the drive spur gear **84** about the axis **86**. The illustrated cam shaft **94** includes opposite cam grooves **96***a*, **96***b* that define pathways for respective balls **98***a*, **98***b*. The illustrated impact mechanism **60** further includes a hammer **100** that includes opposite cam grooves **102***a*, **102***b* that are substantially mirror-images of cam grooves **96***a*, **96***b*. The balls **98***a*, **98***b* are retained between the respective cam grooves **96***a*, **96***b*, **102***a*, **102***b*. The hammer **100** also includes hammer jaws **104***a*, **104***b*.

The motor **16** drives the gear assembly **58** and the impact mechanism **60** to drive rotation of the output drive **88**, as shown in the illustrated embodiment. The output drive **88** is rotated about the axis **86**, which is non-parallel to the axis **42**. In the illustrative embodiment of FIGS. **1-4**, the axis **86** is perpendicular to the axis **42**. In other embodiments (not shown), the axis **86** may be at any acute or obtuse angle to the axis **42**.

In the illustrative embodiment of FIGS. **1-4**, a cylindrical spring **106** is positioned between the drive spur gear **84** and the hammer **100** to bias the hammer **100** away from the drive spur gear **84**. The spring **106** surrounds a portion of the cam shaft **94**. In the illustrated embodiment, the spring **106** rotates with the drive spur gear **84** and the bearing **90***c* permits the hammer **100** to rotate with respect to the spring **106**. Other configurations are possible, and the illustrated configuration is given by way of example only.

The illustrated output drive **88** is integrally formed with anvil jaws **108***a*, **108***b* to create an anvil **110** of the impact mechanism **60**. In other embodiments, the output drive **88** may be coupled to the anvil **110** (such that rotation of the anvil **110** drives rotation of the output drive **88**). The anvil **110** is supported for rotation within the housing body **46** by the bearing **90***a*. The hammer jaws **104***a*, **104***b* impact the anvil jaws **108***a*, **108***b* to drive the output drive **88** in response to rotation of the drive spur gear **84**. In particular, the hammer jaws **104***a*, **104***b* rotate to periodically deliver an impact load to the anvil jaws **108***a*, **108***b* and, thereby, cause intermittent rotation of the output drive **88**.

In the illustrative embodiment of FIGS. **1-4**, the impact cycle of the impact mechanism **60** is illustrated in FIGS. **5**A-**5**J. The spring **106** permits the hammer **100** to rebound after impact, and balls **98***a*, **98***b* guide the hammer **100** to ride up around the cam shaft **94**, such that hammer jaws **104***a*, **104***b* are spaced axially from the anvil jaws **108***a*, **108***b*. The hammer jaws **104***a*, **104***b* are permitted to rotate past the anvil jaws **108***a*, **108***b* after the rebound. In other words, as the hammer **100** rotates about the axis **86**, the hammer **100** also reciprocally translates along the axis **86** (due to the balls **98***a*, **98***b* and the spring **106**). FIGS. **5**A-**5**J illustrate one impact cycle of the impact mechanism **60** of FIGS. **1-4**. It will be appreciated that the impact cycle illustrated in FIGS. **5**A-**5**J is exemplary in nature and that, in other embodiments, impact mechanisms with different impact cycles may be used.

FIGS. **6** and **7** illustrate another embodiment of a work attachment **214** for use with an angle impact tool. The work attachment **214** may be coupled to a handle and a motor **216** having a rotor **240** (i.e., an output shaft). The motor **216** is supported by a motor housing **218**. The illustrated motor **216** is an electric motor, but any suitable prime mover (such as the pneumatic motor disclosed in U.S. Pat. No. 7,886,840) may be utilized. Although not specifically illustrated, a battery and a directional reverse switch may be provided on the angle impact tool, in some embodiments.

The work attachment **214** includes a housing **246**, **248** that is partitioned into two sections, namely, a housing body **246** and a housing cap **248**. As described in greater detail below (with reference to the illustrative embodiment of FIGS. **8-12**), the housing **246**, **248** is partitioned along a parting plane that is perpendicular to an output axis **286** of the work attachment **214**. The housing body **246** and the housing cap **248** cooperate to support a gear assembly **258** and an impact mechanism **260**.

The rotor **240** of the motor **216** rotates about a longitudinal handle axis **242**. In the illustrative embodiment of FIGS. **6** and **7**, the gear assembly **258** includes a bevel gear set comprising a bevel gear **262** and a bevel gear **266**. The bevel gear **262** is coupled to the rotor **240** for rotation with the rotor **240** about the longitudinal handle axis **242**. A bearing **264** is positioned between the bevel gear **262** and the motor housing **218**. The bevel gear **266** meshes with the bevel gear **262**. The bevel gear **266** is coupled to a shaft **268** for rotation with the shaft **268**. The shaft **268** is supported in the housing **246**, **248** of the work attachment **214** by bearings **270***a*, **270***b*. The shaft **268** includes a splined portion **272** near bearing **270***b*. The shaft **268** rotates about an axis **274**. The splined portion **272** functions as a spur gear and, in some embodiments, can be replaced with a spur gear.

In the illustrative embodiment of FIGS. **6** and **7**, the gear assembly **258** also includes a spur gear set comprising the splined portion **272** of shaft **268**, an idler spur gear **276**, and a drive spur gear **284**. Rotation of the splined portion **272** of shaft **268** causes rotation of the idler spur gear **276** about an axis **278**. The idler spur gear **276** is coupled to a shaft **280** for rotation with the shaft **280** about the axis **278**. The shaft **280** is supported in the housing **246**, **248** of the work attachment **214** by bearings **282***a*, **282***b*.

The idler spur gear **276** meshes with the drive spur gear **284** to cause rotation of the drive spur gear **284** about an axis **286**. The drive spur gear **284** is coupled to an output drive **288** through the impact mechanism **260** for selectively rotating the output drive **288**. The drive spur gear **284** and the output drive **288** are supported for rotation within the housing **246**, **248** of the work attachment **214** by bushing **290***a* and bearings **290***b*, **290***c*. The output drive **288** is illustratively embodied as a square drive that may be connected to a socket or other fastener-driving output element.

In the illustrative embodiment of FIGS. **6** and **7**, the axes **274**, **278**, and **286** are all parallel to each other and are all perpendicular to axis **242**. It is contemplated that, in other embodiments, one or more of the axes **274**, **278**, and **286** may be oriented at another angle that is non-parallel to axis **242**.

The impact mechanism **260** may be embodied as any type of impact mechanism. In the illustrative embodiment of FIGS. **6** and **7**, the impact mechanism **260** is a ball-and-cam-type impact mechanism. The impact mechanism **260** includes a cam shaft **294** coupled to the drive spur gear **284** for rotation with the drive spur gear **284** about the axis **286**. The illustrated cam shaft **294** includes opposite cam grooves **296***a*, **296***b* that define pathways for respective balls **298***a*, **298***b*. The illustrated impact mechanism **260** further includes a hammer **300** that includes opposite cam grooves **302***a*, **302***b* that are substantially mirror-images of cam grooves **296***a*, **296***b*. The balls **298***a*, **298***b* are retained between the respective cam grooves **296***a*, **296***b*, **302***a*, **302***b*. The hammer **300** also includes hammer jaws **304***a*, **304***b*.

The motor **216** drives the gear assembly **258** and the impact mechanism **260** to drive rotation of the output drive **288**, as shown in the illustrated embodiment. The output drive **288** is rotated about the axis **286**, which is non-parallel to the axis **242**. In the illustrative embodiment of FIGS. **6** and **7**, the axis **286** is perpendicular to the axis **242**. In other embodiments (not shown), the axis **286** may be at any acute or obtuse angle to the axis **242**.

In the illustrative embodiment of FIGS. **6** and **7**, a cylindrical spring **306** is positioned between the drive spur gear **284** and the hammer **300** to bias the hammer **300** away from the drive spur gear **284**. The spring **306** surrounds a portion of the cam shaft **294**. In the illustrated embodiment, the spring **306** rotates with the drive spur gear **284**, and the bearing **290***c* permits the hammer **300** to rotate with respect to the spring **306**. Other configurations are possible, and the illustrated configuration is given by way of example only.

The illustrated output drive **288** is integrally formed with anvil jaws **308***a*, **308***b* to create an anvil **310** of the impact mechanism **260**. In other embodiments, the output drive **288** may be coupled to the anvil **310** (such that rotation of the anvil **310** drives rotation of the output drive **288**). The anvil **310** is supported for rotation within the housing body **246** by the bushing **290***a*. The hammer jaws **304***a*, **304***b* impact the anvil jaws **308***a*, **308***b* to drive the output drive **288** in response to rotation of the drive spur gear **284**. In particular, the hammer jaws **304***a*, **304***b* rotate to periodically deliver an impact load to the anvil jaws **308***a*, **308***b* and, thereby, cause intermittent rotation of the output drive **288**. The impact cycle of the impact mechanism **260** is similar to the impact cycle illustrated in FIGS. **5**A-**5**J. It will be appreciated that the impact cycle illustrated in FIGS. **5**A-**5**J is exemplary in nature and that, in other embodiments, impact mechanisms with different impact cycles may be used.

FIG. **8** illustrates yet another illustrative embodiment of an angle impact tool **410**. The angle impact tool **410** includes a handle assembly **412** and a work attachment **414** coupled to the handle assembly **412**. As described in more detail below, the handle assembly **412** supports a motor **416**, and the work attachment **414** supports a gear assembly **458**, an impact mechanism **460**, and an output drive **488**. While the tool **410** is in use, torque generated by the motor **416** is transferred via the gear assembly **458** to the impact mechanism **460**, which in turn delivers torque (via a series of powerful rotary blows) to the output drive **488**.

The handle assembly **412** extends along a longitudinal handle axis **442**, as shown in FIG. **8**. The handle assembly **412** illustratively includes a handle housing section **422** and a handle housing section **424**, as best seen in FIG. **9**. A plurality of fasteners (not shown) are used to secure the two handle housing sections **422**, **424** together. As shown in FIGS. **9** and **10**, the handle assembly **412** supports the motor **416** such that an output shaft **440** of the motor **416** (e.g., the illustrated rotor **440**) is rotatable about the axis **442**. The illustrated motor **416** is an electric motor, but any suitable prime mover (such as the pneumatic motor disclosed in U.S. Pat. No. 7,886,840) may be utilized.

As shown in FIGS. **8** and **10**, the work attachment **414** supports the output drive **488** for rotation about an output axis **486**. Torque generated by the motor **416** is transferred via the gear assembly **458** to the impact mechanism **460** to cause the output drive **488** to rotate about the axis **486**. In the illustrative embodiment of FIGS. **8**-**12**, the axis **486** is perpendicular to the axis **442** such that the tool **410** is a right-angle impact tool. In other embodiments (not shown), the axis **486** may be at any acute or obtuse angle to the axis **442**.

The work attachment **414** includes a housing **446**, **448** that is partitioned into two (or more) sections. In other words, the housing **446**, **448** of the work attachment **414** includes a housing section **446** and a housing section **448** that are physically separable from one another. In the illustrative embodiment of FIGS. **8**-**12**, the housing **446**, **448** is partitioned along a parting plane **423** into a housing body **446** and a housing cap **448**. The parting plane **423** is defined by the line **423** shown in FIG. **8** and by a line traveling directly into and out of the page of FIG. **8**. In this illustrative embodiment, the parting plane **423** that primarily separates the housing body **446** and the housing cap **448** is perpendicular (i.e., orthogonal) to the output axis **486** of the work attachment **414**. Furthermore, in this illustrative embodiment, the parting plane **423** is parallel to the axis **442** and is spaced apart from the axis **442** away from the output drive **488**. In other words, as illustrated in FIG. **8**, the axis **442** intersects the axis **486** between the position of the output drive **488** along the axis **486** and a point **433** at which the axis **486** intersects the parting plane **423**.

As shown in the illustrative embodiment of FIG. **8**, the housing body **446** and the housing cap **448** are also partitioned along a parting plane **425** that is perpendicular (i.e., orthogonal) to the axis **442**. The parting plane **425** is defined by the line **425** shown in FIG. **8** and by a line traveling directly into and out of the page of FIG. **8**. In this illustrative embodiment, the parting plane **425** is parallel to the axis **486** and is spaced apart from the axis **486** toward a rear end **520** of the work attachment **414** that is coupled to the handle assembly **412**. As such, when the housing cap **448** is coupled to the housing body **446**, the housing cap **448** abuts the housing body **446** along a portion of the parting plane **423** that extends from a front end **522** of the work attachment **414** (opposite the rear end **520** of the work attachment **414**) to the parting plane **425**. Similarly, when the housing cap **448** is coupled to the housing body **446**, the housing cap **448** abuts the housing body **446** along a portion of the parting plane **425** that extends from an exterior profile **455** of the housing cap **448** to the parting plane **423**.

Although the housing **446**, **448** of the work attachment **414** is illustrated in FIGS. **8-12** (and will be generally described herein) as being partitioned along the parting planes **423**, **425**, it is contemplated that the housing **446**, **448** may alternatively be partitioned along different parting planes in other embodiments. For instance, in one illustrative embodiment, the housing **446**, **448** may be partitioned into two housing sections along a parting plane **423'**. This parting plane **423'** is defined by the line **423'** shown in FIG. **8** and by a line traveling directly into and out of the page of FIG. **8**. Like the parting plane **423**, the parting plane **423'** that primarily separates the housing sections **446**, **448** in this embodiment is perpendicular to the output axis **486** of the work attachment **414** and parallel to the axis **442**. In contrast to the parting plane **423**, however, the parting plane **423'** is spaced apart from the axis **442** toward (rather than away) from the output drive **488**. In other words, as illustrated in FIG. **8**, the parting plane **423'** intersects the axis **486** between the position of the output drive **488** along the axis **486** and a point **435** at which the axis **486** intersects the axis **442**. In this illustrative embodiment, the two housing sections **446**, **448** may also be partitioned by the parting plane **425**.

In another illustrative embodiment, the housing **446**, **448** may be partitioned into two housing sections along a parting plane **423"**. This parting plane **423"** is defined by the line **423"** shown in FIG. **8** and by a line traveling directly into and out of the page of FIG. **8**. Like the parting plane **423** (and the parting plane **423'**), the parting plane **423"** that primarily separates the housing sections **446**, **448** in this embodiment is perpendicular to the output axis **486** of the work attachment **414** and parallel to the axis **442**. In contrast to the parting plane **423** (and the parting plane **423'**), however, the axis **442** lies in the parting plane **423"** (rather than the parting plane **423"** being spaced apart from the axis **442**). In some embodiments, the two housing sections **446**, **448** may also be partitioned along the entire parting plane **423"** from the front end **522** to the rear end **520** of the work attachment **414**.

Just as the housing **446**, **448** may be partitioned by any number of parting planes that are perpendicular to the axis **486** (i.e., other parting planes that are parallel to the illustrated parting planes **423**, **423'**, **423"**), the housing **446**, **448** may also be partitioned by any number of parting planes that are perpendicular to the axis **442** (i.e., other parting planes that are parallel to the illustrated parting plane **425**). As noted above, it is also contemplated that the housing **446**, **448** may be partitioned solely along a parting plane that is perpendicular to the axis **486**, without being partitioned along a secondary parting plane that is perpendicular to the axis **442**. It will also be appreciated that, in embodiments where multiple parting planes are used to partition the housing **446**, **448**, the multiple parting planes need not be perpendicular to one another.

As shown in FIGS. **8** and **9**, the housing cap **448** is removably coupled to the housing body **446** using a plurality of fasteners **450**. When the housing cap **448** is removably coupled to the housing body **446**, each of the fasteners **450** extends through one of a plurality of apertures **451** formed in the housing cap **448** (FIG. **12**) and is received in one of a plurality of bores **453** formed in the housing body **446** (FIG. **11**). In the illustrative embodiment, the fasteners **450** are embodied as threaded fasteners (e.g., screws), while the bores **453** are formed to include internal threading that engages the threaded fasteners **450**. As shown in FIG. **8**, the apertures **451** formed in the housing cap **448** may be recessed from the exterior profile **455** of the housing cap **448**. As such, when the housing cap **448** is removably coupled to the housing body **446**, each of the fasteners **450** is received in one of the apertures **451** such that the fasteners **450** do not extend beyond the exterior profile **455** of the housing cap **448**.

In the illustrative embodiment, the housing body **446** of the work attachment **414** is removably coupled to the handle assembly **412** using a plurality of fasteners **497**, as shown in FIG. **8**. Each of the plurality of fasteners **497** extends through one of a plurality of apertures **499** formed in the housing body **446** (FIG. **11**) and is received in one of a plurality of bores (not shown) formed in the handle assembly **412**. In the illustrative embodiment, the fasteners **497** are embodied as threaded fasteners (e.g., screws), while the bores formed in the handle assembly **412** include internal threading to engage the threaded fasteners **497**. As suggested in FIG. **8**, each of the bores formed in the handle assembly **412** extends along an axis **413**. In the illustrative embodiment, each of the axes **413** is disposed at an acute angle to the axis **442**, such that the axes **413** are non-parallel to the axis **442** and to one another. This configuration may increase the serviceability of the angle impact tool **410** by allowing the fasteners **497** to be more readily installed and removed from the bores formed in the handle assembly **412**. For instance, in one illustrative embodiment, each of the axes **413** intersects the axis **442** at an 11 degree angle.

FIG. **9** illustrates an exploded view of the angle impact tool **410**, including the components of both the handle assembly **412** and the work attachment **414**. As discussed above, the handle assembly **412** includes the handle housing sections **422**, **424** that are coupled together using a plurality of fasteners (not shown). The handle assembly **412** includes a switch **436** that is coupled to a trigger **426** such that actuation of the trigger **426** causes actuation of the switch **436** and, therefore, operation of the motor **416** of the tool **410**. The handle assembly **412** also includes a directional control **427** that is coupled to the switch **436** to control the rotational direction of the output shaft **440** of the motor **416** (i.e., counterclockwise or clockwise about the axis **442**). The trigger **426** and the directional control **427** are each supported by the handle housing sections **422**, **424** such that the trigger **426** and the directional control **427** are both accessible from the exterior of the handle assembly **412**, as shown in FIG. **8**. The switch **436** is also coupled to a battery terminal **428** supported by the handle housing sections **422**, **424** such that, when a battery is coupled to the tool **410**, electrical power is supplied to the switch **436** via the battery terminal **428**.

The handle assembly **412** further includes a motor housing **418** configured to support the motor **416** so that the output shaft **440** extends toward the work attachment **414** when the angle impact tool **410** is assembled as shown in FIG. **10**. The motor **416** is secured within the motor housing **418** via mounting screws **445**. The handle assembly **412** also includes a number of o-rings **434** that are positioned between the motor **416** and the motor housing **418** to radially stabilize the motor **416**.

In the illustrative embodiment shown in FIGS. **9** and **10**, the gear assembly **458** of the work attachment **414** includes a planetary gearset **570**. The planetary gearset **570** includes a central or sun gear **572**, a number of planet gears **574** arranged within a ring gear **576** so that each planet gear **574** meshes with both the sun gear **572** and the ring gear **576**, and a planet carrier **578** coupled to each of the planet gears **574** and supporting each of the planet gears **574** for rotation. The sun gear **572** includes a shaft **430** that extends along the axis **442** and couples to the output shaft **440** of the motor **416** for rotation therewith. It should be appreciated that, in other embodiments, the planetary gearset **570** of the gear assembly **458** may have other configurations.

The gear assembly **458** further includes a bevel gear **462** having a shaft **489** that extends along the axis **442** and is coupled to the planet carrier **578** of the planetary gearset **570** for rotation therewith, as shown in FIGS. **9** and **10**. The bevel gear **462** is supported for rotation about the axis **442** by a needle bearing **439** and a spindle bearing **495**. The work attachment **414** also includes a spacer **437** positioned between the bearing **495** and the ring gear **576** of the planetary gearset **570**, as shown in FIGS. **9** and **10**.

The gear assembly **458** also includes a bevel gear **466** that meshes with the bevel gear **462**. The bevel gear **466** is mounted on a shaft **468** for rotation therewith about an axis **463** that is perpendicular to the axis **442**, as shown in FIG. **10**. The shaft **468** is supported for rotation in the housing **446**, **448** of the work attachment **414** by bearings **470***a*, **470***b* of the gear assembly **458**. A spur gear **472** of the gear assembly **458** is mounted on the shaft **468** for rotation therewith, as shown in FIGS. **9** and **10**.

The gear assembly **458** further includes a drive spur gear **484** that meshes with the spur gear **472**, as shown in FIG. **10**. The drive spur gear **484** is mounted on a camshaft **494** of the impact mechanism **460** for rotation therewith about the axis **486**, and the camshaft **494** is supported for rotation in the housing **446**, **448** of the work attachment **414** by a bearing **490***b*. Rotation of the drive spur gear **484** is transferred to the impact mechanism **460** to cause a hammer **400** of the impact mechanism **460** to rotate about the axis **486** (within a sleeve **464** that is sized to receive the hammer **400**). As described above, this rotation of the hammer **400** results in periodic impacts between the hammer **400** and an anvil **411** of the impact mechanism **460**, causing rotation of the anvil **411** (and, hence, the output drive **488**) about the axis **486**.

As shown in FIG. **9**, the output drive **488** of the work attachment **414** is integrally formed with anvil jaws to create the anvil **411** of the impact mechanism **460**. In other embodiments, the output drive **488** may be distinct from and coupled to the anvil **411** (such that rotation of the anvil **411** drives rotation of the output drive **488**). In the illustrative embodiment, the anvil **411** (including the output drive **488**) is supported for rotation relative to the housing body **446** by the bushing **490***a*. The output drive **488** may be configured to connect to a socket or other fastener-driving output element. In the illustrative embodiment, a resilient retainer **511** is positioned near an end of the output drive **488** opposite the anvil jaws, as shown in FIGS. **9** and **10**. When a socket is connected to the output drive **488**, the resilient retainer **511** may engage an internal surface or recess of the socket to maintain the socket in engagement with the output drive **488**.

The impact mechanism **460** of the work attachment **414** may be embodied as any suitable type of impact mechanism. As shown in FIGS. **9** and **10**, the impact mechanism **460** is illustratively embodied as a ball-and-cam-type impact mechanism with similar construction and operation to the impact mechanisms **60**, **260** described above with reference to FIGS. **1-7** (except as noted below). For instance, the camshaft **494** and the hammer **400** of the impact mechanism **460** each include cam grooves defined therein that receive respective balls to couple the hammer **400** to the camshaft **494**. The camshaft **494** is coupled to the drive spur gear **484** for rotation therewith. As shown in FIGS. **9** and **10**, a key **447** is disposed between the camshaft **494** and the drive spur gear **484**, and a retaining ring **449** is also used to maintain the position the drive spur gear **484** on the camshaft **494**.

As illustrated in FIGS. **9** and **10**, the work attachment **414** includes a conical spring **506** positioned between the drive spur gear **484** and the hammer **400** of the impact mechanism **460** (rather than a cylindrical spring, like the springs **106**, **306** positioned between the drive spur gears **84**, **284** and the hammers **100**, **300** of the impact mechanisms **60**, **260**). The conical spring **506** biases the hammer **400** away from the drive spur gear **484** (such that hammer jaws of the hammer **400** are moved into engagement with the anvil jaws of the anvil **411**). The conical spring **506** surrounds a portion of the camshaft **494**.

As best seen in FIG. **10**, the conical spring **506** has a generally conical (or frusto-conical) cross-section. In other words, one end of the conical spring **506** is wider, or has a larger diameter, than the opposite end of the conical spring **506**. In the illustrative embodiment, an end of the conical spring **506** that is coupled to the drive spur gear **484** has a smaller diameter than an opposite end of the conical spring **506** that is coupled to the hammer **400**. It is contemplated that, in other embodiments, the end of the conical spring **506** that is coupled to the drive spur gear **484** may have a larger smaller diameter than the opposite end of the conical spring **506** that is coupled to the hammer **400**.

In the illustrated embodiment, the conical spring **506** rotates with the drive spur gear **484**, and a washer **452** and a plurality of thrust balls **456** cooperate to form a bearing **490***c* that permits the hammer **400** to rotate about the axis **486** with respect to the conical spring **506**. In other embodiments, the conical spring **506** may rotate with the hammer **400** and a bearing may permit the drive spur gear **484** to rotate with respect to the conical spring **506**.

It is believed that the conical spring **506** may provide several advantages over the cylindrical springs **106**, **306**. For instance, the conical spring **506** may have a longer service life than the cylindrical springs **106**, **306**. The conical spring **506** may also have a smaller solid height than the cylindrical springs **106**, **306**, while maintaining similar performance. Decreasing the solid height of the conical spring **506** may allow for a decrease in the overall height of the work attachment **414**. In the illustrative embodiment of FIG. **9**, the smaller diameter of the end of the conical spring **506** coupled to the drive spur gear **484** may also allow the drive spur gear **484** to have a smaller diameter, further decreasing the dimensions of the work attachment **414**.

As shown in FIG. **9** (and discussed in detail above), the housing **446**, **448** of the work attachment **414** is partitioned into the housing body **446** and the housing cap **448**. When the housing cap **448** is removably coupled to the housing body **446** using the fasteners **450**, a gasket **457** is positioned between the housing body **446** and the housing cap **448** to provide a fluid seal for the housing **446**, **448**.

As shown in FIGS. **9-11**, the housing body **446** is formed to include a bore **459** that extends along the axis **442**, a bore **461** that extends along the axis **486**, and a bore **465** that extends along the axis **463**. As discussed above, in the illustrative embodiment of FIGS. **8-12**, the axes **463**, **486** are parallel to one another and each perpendicular to the axis **442**. The bore **465** is positioned between the bores **459** and **461**, such that the bore **465** overlaps each of the bore **459** and the bore **461**. In other words, in the illustrative embodiment, the bore **465** is in direct fluid communication with both the bore **459** and the bore **461**. When the work attachment **414** is assembled and the housing cap **448** is removably coupled to the housing body **446** (as shown in FIG. **10**), the impact mechanism **460** is positioned in the bore **461** and the gear assembly **458** is positioned primarily within the bores **459**, **465** (though the drive spur gear **484** of the gear assembly **458** is also positioned in the bore **461**).

As best seen in the cross-sectional view of FIG. **10**, the bore **459** is formed in the housing body **446** such that the bore **459** includes several bore sections having differing diameters from one another. More specifically, the bore **459** includes a bore section **477**, a bore section **479**, a bore section **481**, and a bore section **483**, each of which has a successively smaller diameter than the previous section (moving from the rear end **520** of the work attachment **414** toward the front end **522** of the work attachment **414**). Each of the bore sections of bore **459**, and the components positioned therein when the work attachment **414** is assembled (as shown in FIG. **10**) are discussed in more detail below.

The ring gear **576** of the planetary gearset **570** is positioned in the bore section **477** of the bore **459**, as shown in FIG. **10**. The bore section **477** is bounded by an internal surface **485** of the housing body **446** that defines a diameter of the bore section **477**. The ring gear **576** is engaged with the internal surface **485** such that the ring gear **576** is fixed relative to the housing body **446**. As shown in FIG. **10**, the sun gear **572**, the planet gears **574**, the planet carrier **578**, and a section **508** of the shaft **489** of the bevel gear **462** are also each at least partially positioned in the bore section **477**.

The spacer **437** is positioned in the bore section **479** between the ring gear **576** and the bearing **495**. The bore section **479** is bounded by an internal surface **487** of the housing body **446** that defines a diameter of the bore section **479**. The diameter of the bore section **479** is less than the diameter of the bore section **477**. The spacer **437** is positioned in the bore section **479** such that the spacer **437** is engaged with the internal surface **487**. The section **508** of the shaft **489** of the bevel gear **462** extends through the bore section **479** along the axis **442**.

The bearing **495** is positioned in the bore section **481** between the spacer **437** and the bearing **439**. The bore section **481** is bounded by an internal surface **491** of the housing body **446** that defines a diameter of the bore section **481**. The diameter of the bore section **481** is less than the diameter of the bore section **479**. The section **508** of the shaft **489** of the bevel gear **462** also extends through the bore section **481** along the axis **442**. The bearing **495** engages both the internal surface **491** and the section **508** of the shaft **489** to support the bevel gear **462** for rotation about the axis **442**.

The bearing **439** is positioned in the bore section **483** between the bearing **495** and the bore **465**, as shown in FIG. **10**. The bore section **483** is bounded by an internal surface **510** of the housing body **446** that defines a diameter of the bore section **483**. The diameter of the bore section **483** is less than the diameter of the bore section **481**. A section **512** of the shaft **489** of the bevel gear **462** extends through the bore section **483** along the axis **442**. A diameter of the section **512** of the shaft **489** is greater than a diameter of the section **508** of the shaft **489** discussed above. The bearing **439** engages both the internal surface **510** and the section **512** of the shaft **489** to support the bevel gear **462** for rotation about the axis **442**. As shown in FIG. **10**, the bearing **495** (positioned in the bore section **481**) abuts both the section **512** of the shaft **489** and the internal surface **510** of the housing body **446**, which serves to properly align the bevel gears **462**, **466**.

During operation of the tool **410**, rotation of the output shaft **440** of the motor **416** will be transferred to the sun gear **572** (via the shaft **430** of the sun gear **572**). Rotation of the sun gear **572** relative to the ring gear **576** will cause the planet gears **574** to travel about the sun gear **572**. Travel of the planet gears **574** causes rotation of the planet carrier **578** which is coupled to the bevel gear **462** such that rotation of the planet carrier **578** drives rotation of the bevel gear **462**.

The bevel gear **462** extends along the axis **442** into the bore **465** such that the bevel gear **462** meshes with the bevel gear **466** positioned in the bore **465**. The bevel gear **466** is coupled to an end **513** of the shaft **468** for rotation therewith about the axis **463**. The end **513** of the shaft **468** is supported for rotation in the bore **465** by the bearing **470***b*. The shaft **468** extends through the bore **465** along the axis **463** to an end **515** opposite the end **513**. The spur gear **472** is coupled to the end **515** of the shaft **468** for rotation therewith about the axis **463**. The end **515** of the shaft **468** is supported for rotation by the bearing **470***a*.

As best seen in FIG. **12**, the housing cap **448** is formed to include a bore **516** that extends along the axis **463** when the housing cap **448** is removably coupled to the housing body **446**. As such, when the housing cap **448** is removably coupled to the housing body **446** as shown in FIG. **10**, the bore **465** is aligned with the bore **516** such that the bearing **470***a* and the spur gear **472** are received in the bore **516**.

During operation of the tool **410**, rotation of the bevel gear **462** about the axis **442** will drive rotation of the bevel gear **466** about the axis **463**. Rotation of the bevel gear **466** causes the shaft **468** to rotate about the axis **463**, thereby causing the spur gear **472** to rotate about the axis **463**.

In the illustrative embodiment, the impact mechanism **460** is positioned in the bore **461** such that a portion of the anvil **411** including the output drive **488** extends along the axis **486** through a bottom face **530** of the housing body **446** to a point outside of the housing body **446**. As discussed above, the anvil **411** (including the output drive **488**) is supported for rotation about the axis **486** by the bushing **490***a* which is positioned adjacent the bottom face **530** of the housing body **446**, as shown in FIG. **10**. The hammer **400** is coupled for rotation with the camshaft **494** about the axis **486**, and the camshaft **494** is supported for rotation about the axis **496** by the bearing **490***b*.

As best seen in FIG. **12**, the housing cap **448** is formed to include a bore **518** that extends along the axis **486** when the housing cap **448** is removably coupled to the housing body **446**. As such, when the housing cap **448** is removably coupled to the housing body **446** as shown in FIG. **10**, the bore **461** is aligned with the bore **518** such that the bearing **490***b* and the drive spur gear **484** are received in the bore **518**.

During operation of the tool **410**, rotation of the spur gear **472** about the axis **463** drives rotation of the drive spur gear **484** about the axis **486**. Rotation of the drive spur gear **484** causes the camshaft **494** to rotate about the axis **486**, thereby causing the hammer **400** to rotate about the axis **486**. As discussed above, as the hammer **400** rotates about the axis **486**, the hammer **400** also reciprocally translates along the axis **486** to periodically deliver an impact load to the anvil **411**. These impact blows cause intermittent rotation of the anvil **411** and, hence, the output drive **488**.

Referring now to FIG. **11**, the housing body **446** is shown in a detailed perspective view (without the remaining components of the work attachment **414**). As mentioned above, the housing body **446** includes a rear end **520** configured to couple to the handle assembly **412** and a front end **522** opposite the rear end **520**. As shown in FIG. **11**, and discussed in greater detail below, the housing body **446** also includes a side **524**, a side **526**, a top face **528**, and the bottom face **530** as shown in FIG. **11**.

The rear end **520** of the housing body **446** includes a receiving surface **532** defining an exterior profile **533** and a coupling surface **534** that is recessed from the exterior profile **533** such that the coupling surface **534** does not extend beyond the exterior profile **533**. The receiving surface **532** interconnects with the coupling surface **534**, as shown in FIG. **11**. The rear end **520** is configured to couple to the handle assembly **412** such that the handle housing sections **422**, **424** of the handle assembly **412** extend past the receiving surface **532** to engage the coupling surface **534** to permit the housing body **446** to be coupled to the handle assembly **412** using the plurality of fasteners **497**. As shown in FIG. **11**, the bore **459** is formed in the coupling surface **534** such that the bore **459** extends along the axis **442**.

The front end **522** of the housing body **446** is arranged in closer proximity to the bore **461** than the rear end **520**, as shown in FIG. **11**. The bore **459** extends from the rear end **520** along the axis **442** toward the front end **522** and overlaps the bore **465**, as shown in FIGS. **10** and **11**. The sides **524**, **526** of the housing body **446** are arranged opposite one another and, in the illustrative embodiments, are mirror images of one another. Each of the sides **524**, **526** interconnects with each of the ends **520**, **522**.

The bottom face **530** of the housing body **446** is interconnected with each of the ends **520**, **522** and each of the sides **524**, **526**. In the illustrative embodiment, the bore **461** extends through the bottom face **530** along the axis **486**, while the bore **465** does not extend through the bottom face **530**. The top face **528** of the housing body **446** is arranged opposite the bottom face **530**. The top face **528** interconnects with each of the ends **520**, **522** and each of the sides **524**, **526**. The top face **528** includes a section **536** that interconnects with the rear end **520** and a section **538** that interconnects with the front end **522**. As shown in FIG. **11**, the sections **536**, **538** interconnect with one another.

The section **536** of the top face **528** of the housing body **446** includes a surface **540** that extends from the rear end **520** toward the section **538**. The section **536** also includes a surface **542** that interconnects with the surface **540** and extends parallel to the axes **463**, **486** and perpendicular to the axis **442** (i.e., along the parting plane **425**) to connect with the section **538**. The apertures **499** discussed above are formed in the surface **540** such that the apertures **499** extend through the coupling surface **534** of the rear end **520** of the housing body **446**, as shown in FIG. **11**. Similar to the bores of the handle assembly **412** that receive the fasteners **497** when the handle assembly **412** is coupled to the housing body **446**, each of the apertures **499** formed in the surface **540** extends at an acute angle relative to the axis **442**. As such, a cutout section **544** is formed in the surface **540** adjacent to each of the apertures **499**.

The section **538** of the top face **528** of the housing body **446** includes a surface **546** that is coupled to the surface **542** and extends perpendicular to the axes **463**, **486** and parallel to the axis **442** (i.e., along the parting plane **423**) toward the front end **522**. The surface **546** is positioned closer to the axis **442** than the surface **540**, as shown in FIG. **11**. The bores **465**, **461** extend through the surface **546** along the axes **463**, **486**, respectively. In the illustrative embodiment, four bores **453** formed in the housing body **446** also extend through the surface **546**. As discussed above, the bores **453** are configured to receive fasteners **450** that removably couple the housing cap **448** to the housing body **446**.

In the illustrative embodiment shown in FIG. **11**, the section **538** of the top face **528** of the housing body **446** also includes a shoulder **548** that protrudes from the surface **546** in a direction parallel to the axes **463**, **486** and away from the axis **442**. Likewise, the section **536** of the top face **528** of the housing body **446** includes a shoulder **549** that protrudes from the surface **542** in a direction parallel to the axis **442** and toward the axes **463**, **486**. In other words, the shoulders **548**, **549** of the housing body **446** each protrude toward the housing cap **448** when the housing **446**, **448** is assembled (see FIG. **10**).

Referring now to FIG. **12**, the housing cap **448** is shown in a detailed perspective view (without the remaining components of the work attachment **414**). The housing cap **448** includes a rear end **550**, an front end **552**, a side **554**, a side **556**, a bottom face **558**, and a top face **560**. The rear end **550** of the housing cap **448** includes a surface **541** that is configured to engage the shoulder **549** of the housing body **446** when the housing cap **448** is removably coupled to the housing body **446**. The rear end **550** of the housing cap **448** also includes a lip **568** that protrudes from the surface **541** in a direction parallel to the axis **442** (when the housing cap **448** is removably coupled to the housing body **446**) and away from the axes **463**, **486**. The lip **568** is configured to engage the surface **542** of the housing body **446** when the housing cap **448** is removably coupled to the housing body **446**. In particular, the lip **568** of the housing cap **448** abuts the surface **542** of the housing body **446** along the parting plane **425**. The front end **552** of the housing cap **448** is arranged opposite the rear end **550** such that the front end **552** is aligned with the front end **522** of the housing body **446** when the housing cap **448** is removably coupled to the housing body **446**.

The bottom face **558** of the housing cap **448** is configured to abut the section **538** of the top face **528** of the housing body **446** when the housing cap **448** is removably coupled to the housing body **446**. The bottom face **558** of the housing cap **448** includes a surface **562** that is coupled to the surface **541** and extends perpendicular to the axes **463**, **486**. The surface **562** is configured to engage the shoulder **548** of the housing body **446** when the housing cap **448** is removably coupled to the housing body **446**. The bottom face **558** of the housing cap **448** also includes a lip **566** that protrudes from the surface **562** in a direction parallel to the axes **463**, **486** and toward the axis **442** (when the housing cap **448** is removably coupled to the housing body **446**). In other words, the lip **566** (as well as the lip **568**) of the housing cap **448** protrudes toward the housing body **446** when the housing **446**, **448** is assembled (see FIG. **10**). The lip **566** is configured to engage the surface **546** of the housing body **446** when the housing cap **448** is removably coupled to the housing body **446**. In particular, the lip **566** of the housing cap **448** abuts the surface **546** of the housing body **446** along the parting plane **423**.

The bottom face **558** is formed to include the bores **516**, **518** described above. The bore **516** includes a bore section **517** sized to receive the bearing **470***a* and a bore section **519** sized to receive the spur gear **472**. The bore **518** includes a bore section **521** sized to receive the bearing **490***b* and a bore section **523** sized to receive the drive spur gear **484**. When the housing **446**, **448** is assembled, the lips **566**, **568** engage the corresponding shoulders **548**, **549** such that the bores **461**, **518** are aligned with one another and the bores **465**, **516** are aligned with one another. The apertures **451** (which receive the fasteners **450**, as discussed above) are formed in the lip **566** such that the plurality of apertures **451** extend from the bottom face **558** to the top face **560**, as shown in FIG. **12**.

In the illustrative embodiment, the work attachment **414** also includes a number of alignment pins **473** (FIG. **9**). As shown in FIG. **11**, the housing body **446** includes a corresponding number of non-threaded bores **454**. Similarly, as shown in FIG. **12**, the housing cap **448** includes a corresponding number of non-threaded bores **564**. When the housing cap **448** is brought into engagement with the housing body **446**, each of the alignment pins **473** is received in a corresponding bore **454** of the housing body **446** and a corresponding bore **564** of the housing cap **448**. In this embodiment, the pins **473** will align the bores **461**, **518** and will align the bores **465**, **516** while the housing cap **448** is removably coupled to the housing cap **448**.

Head height dimensions **114**, **314**, **614** of the work attachments **14**, **214**, **414** are illustrated in FIGS. **4**, **7**, and **10**, respectively. The head height dimension **114**, **314**, **614** is the distance (measured parallel to the output axis **86**, **286**, **486**) from the top of the housing cap **48**, **248**, **448** to the bottom of the housing body **46**, **246**, **446**. The motor housings **18**, **218**, **418** define analogous motor housing height dimensions **118**, **318**, **618**, as shown in FIGS. **4**, **7**, and **10**. It may be desirable to reduce the head height dimensions **114**, **314**, **614** so that the work attachments **14**, **214**, **414** can fit into small spaces. As suggested in the drawings, the illustrative embodiments of the present disclosure allow the head height dimensions **114**, **314**, **614** to be equal to or smaller than the corresponding motor housing height dimensions **118**, **318**, **618**. Such configurations permit insertion of the angle impact tools into smaller spaces than has previously been achievable, without compromising torque.

While certain illustrative embodiments have been described in detail in the figures and the foregoing description, such an illustration and description is to be considered as exemplary and not restrictive in character, it being understood that only illustrative embodiments have been shown and described and that all changes and modifications that come within the spirit of the disclosure are desired to be protected. There are a plurality of advantages of the present disclosure arising from the various features of the apparatus, systems, and methods described herein. It will be noted that alternative embodiments of the apparatus, systems, and methods of the present disclosure may not include all of the features described yet still benefit from at least some of the advantages of such features. Those of ordinary skill in the art may readily devise their own implementations of the apparatus, systems, and methods that incorporate one or more of the features of the present disclosure.

The invention claimed is:

1. An angle impact tool comprising:

a handle assembly extending along a first axis and supporting a motor, the motor including a shaft configured to rotate about the first axis;

a work attachment coupled to the handle assembly, the work attachment comprising:

an impact mechanism including an anvil configured to rotate about a second axis that is non-parallel to the first axis and a hammer configured to rotate about the second axis to periodically deliver an impact load to the anvil to cause rotation of the anvil about the second axis;

a gear assembly configured to transfer rotation from the shaft of the motor to the hammer of the impact mechanism;

a housing supporting the impact mechanism and the gear assembly, wherein the housing is partitioned along a first parting plane that is perpendicular to the second axis such that the housing includes a first housing section and a second housing section;

wherein the first axis is parallel to the first parting plane; and

wherein the first and second housing sections are also partitioned along a second parting plane that is perpendicular to the first axis.

2. The angle impact tool of claim **1**, wherein the first axis lies in the first parting plane.

3. The angle impact tool of claim **1**, wherein the first axis is spaced apart from the first parting plane.

4. The angle impact tool of claim **3**, wherein the first axis intersects the second axis between (i) a position of the anvil along the second axis and (ii) a point at which the second axis intersects the first parting plane.

5. The angle impact tool of claim **3**, wherein the first parting plane intersects the second axis between (i) a position of the anvil along the second axis and (ii) a point at which the second axis intersects the first axis.

6. The angle impact tool of claim **1**, wherein the second housing section is removably coupled to the first housing section by a plurality of fasteners, each of the plurality of fasteners extending through a corresponding aperture formed in the second housing section and being received in a corresponding bore formed in the first housing section.

7. The angle impact tool of claim **6**, wherein each of the corresponding apertures formed in the second housing section is recessed from an exterior profile of the second housing section such that each of the plurality of fasteners that removably couples the second housing section to the first housing section does not extend beyond the exterior profile of the second housing section.

8. The angle impact tool of claim **6**, further comprising a gasket positioned between the first and second housing sections to provide a fluid seal when the second housing section is removably coupled to the first housing section by the plurality of fasteners.

9. The angle impact tool of claim **1**, wherein:

the first housing section is formed to include a first bore extending along the first axis, a second bore extending along the second axis, and a third bore extending along a third axis that is parallel to the second axis, the third bore being positioned between the first and second bores and overlapping both the first and second bores;

the impact mechanism is positioned in the second bore; and

the gear assembly is positioned at least partially within the first and third bores.

10. The angle impact tool of claim **9**, wherein the second housing section is formed to include a fourth bore extending along the second axis and a fifth bore extending along the third axis.

11. The angle impact tool of claim **10**, wherein the work attachment further comprises a plurality of pins that each extend into a corresponding bore formed in the first housing section and into a corresponding bore formed in the second housing section such that the plurality of pins align the fourth bore with the second bore and the fifth bore with the third bore.

12. The angle impact tool of claim **10**, wherein:

the first housing section is formed to include a shoulder that protrudes toward the second housing section; and

the second housing section is formed to include a lip that protrudes toward the first housing section, the lip engaging the shoulder such that the fourth bore is aligned with the second bore and the fifth bore is aligned with the third bore.

13. The angle impact tool of claim **9**, wherein the gear assembly includes (i) a first bevel gear positioned in the first bore of the first housing section and configured to rotate about the first axis and (ii) a second bevel gear positioned in the third bore of the first housing section and configured to rotate about the third axis, and wherein the second bevel gear meshes with the first bevel gear.

14. The angle impact tool of claim **13**, wherein:

the first bore comprises adjacent first and second bore sections, the second bore section having a smaller diameter than the first bore section and being located closer to the third bore than the first bore section, the first bore section being bounded by a first internal surface of the first housing section, the second bore section being bounded by a second internal surface of the first housing section;

the first bevel gear includes a shaft that extends along the first axis and comprises adjacent first and second shaft sections, the second shaft section having a larger diameter than the first shaft section, the first shaft section being positioned within the first bore section, the second shaft section being positioned within the second bore section; and

a bearing that supports the first bevel gear for rotation about the first axis and engages both the first shaft section and the first internal surface abuts both the second shaft section and the second internal surface to align the first and second bevel gears.

15. The angle impact tool of claim **1**, wherein the work attachment is removably coupled to the handle assembly by a plurality of fasteners, each of the plurality of fasteners extending through a corresponding aperture formed in the first housing section and being received in a corresponding bore formed in the handle assembly, each corresponding bore extending along an axis that is disposed at an acute angle to the first axis.

16. A work attachment comprising:

a housing body configured to be coupled to a motorized tool including a rotatable output shaft, the housing body being formed to include (i) a first bore extending along a first axis, (ii) a second bore extending along a second axis that is perpendicular to the first axis, and (iii) a third bore extending along a third axis that is perpendicular to the first axis, wherein the third bore is positioned between the first and second bores and overlaps both the first and second bores;

an impact mechanism received in the second bore of the housing body, the impact mechanism including a hammer configured to rotate about the second axis to periodically deliver an impact load to an anvil to cause rotation of the anvil about the second axis;

a gear assembly received at least partially in the first and third bores of the housing body, the gear assembly configured to be coupled to the rotatable output shaft of the motorized tool such that rotation of the output shaft about the first axis drives rotation of the hammer about the second axis;

a housing cap removably coupled to the housing body by a plurality of fasteners to enclose the second and third bores, the housing cap abutting the housing body along a first parting plane that is perpendicular to the second and third axes; and

wherein the housing cap also abuts the housing body along a second parting plane that is perpendicular to the first axis.

17. The work attachment of claim **16**, wherein the second parting plane is located between the third axis and an end of the housing body configured to be coupled to the motorized tool.

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